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RESEARCH AND DEVELOPMENT BRANCH

COMMAND AND CONTROL WORKSHOP: REQUIREMENTS AND OPPORTUNITIES FOR C2 R&D

by

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OTTAWA, CANADA

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DEPARTMENT OF NATIONAL DEFENCE

CANADA

OPERATIONAL RESEARCH DIVISION

DIRECTORATE OF OPERATIONAL RESEARCH (JOINT & LAND)

ORD PROJECT REPORT PR 9620

CRAD COMMAND AND CONTROL WORKSHOP: REQUIREMENTS AND OPPORTUNITIES FOR C2 R&D

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ABSTRACT

A workshop on Command and Control (C2) sponsored by the Chief Research and Development (CRAD) was held in Ottawa on 7-9 May 1996. This forum brought together CRAD scientists and Canadian Forces (CF) officers to provide input on strategic planning for Command and Control Research and Development (C2 R&D). Specifically, the group was tasked to address the "what" and the "how" of C2 R&D. This report documents the results of structured brainstorming exercises on the requirements and opportunities (the "what") for C2 R&D in the near to mid-term. A companion paper documents the structures and processes (the "how") recommended to implement productive C2 R&D.

Distinct themes emerged from the syndicate exercise identifying areas for further R&D. Decision support systems and planning tools must be developed to exploit information made available through C2 Information Systems (C2IS). Methods and procedures must be developed to monitor the performance of C2IS. Research is required in determining effective processes for large project C2IS life cycle management from user requirements capture to end user support. Strategies for information management must be developed and built into system architectures. Standards need to be developed for information presentation. Effective programs must be established for initial and operational training. Finally, doctrine must be examined in light of how C2IS technology could assist the CF in achieving its missions. Although present research programs address many of these areas, CRAD does not have the resources to mount major research programs in each of these fields. There was a sense that realignment of research efforts based on a multi-disciplinary team approach may yield better results. Ideas generated and developed by the syndicates are provided in the Annexes.

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RESUME

L'atelier sur le commandement et contrôle, parrainé par le CR Dév, eut lieu à Ottawa du 7 au 9 mai 1996. Ce colloque visait à réunir les scientifiques du CR Dév et les officiers des Forces canadiennes pour jeter les bases d'un plan stratégique pour la recherche en matière de commandement et contrôle (CC R&D). En particulier, l'atelier se proposait de discuter des besoins en recherche et des moyens à mettre en oeuvre dans ce domaine. Ce rapport fait état des propositions à court et moyen termes résultant de la conférence d'idées menée à cette fin. Un document séparé décrit les structures et le processus recommandés pour la mise en oeuvre d'un programme de R&D efficace.

Lors des ateliers, différents thèmes furent abordés débouchant sur de nouveaux champs de recherche. Des systèmes d'aide à la décision et à la planification devront être mis au point pour mieux exploiter l'information générée par les nouveaux systèmes de commandement et contrôle (ISCC). De même, de nouvelles procédures de suivi de performance devront être conçues pour ces ISCC. Des recherches devront être lancées sur les méthodes de gestion du cycle de vie des grands systèmes. Une stratégie de gestion de l'information devra être mise au point et incorporée à la structure même du système. Des normes régissant la présentation des informations devront être élaborées La formation de base et opérationnelle devra aussi être appuyée par des programmes efficaces. Enfin, la doctrine devra être revue en regard de l'impact technologique du ISCC sur la conduite des missions effectuées par les Forces canadiennes. Bien que les programmes de recherche en place traitent de plusieurs de ces questions, le CR Dév ne dispose pas des ressources suffisantes pour lancer des travaux dans chacun de ces domaines. Il appert aussi qu'une réorientation des activités de recherche favorisant une approche d'équipes multidisciplinaires donnerait de meilleurs résultats. Les idées proposées et élaborées par les participants aux ateliers sont présentées en annexe.

EXECUTIVE SUMMARY

The Chief of Research and Development (CRAD) directed that a high-level study be conducted into Command and Control Research and Development (C2 R&D) in the Department of National Defence. As part of this study, a workshop was organized to bring together Canadian Forces (CF) Officers and CRAD scientists to discuss the "what" and the "how" of C2 R&D. This paper discusses the requirements and opportunities for C2 R&D (the "what"). A companion paper discusses the structures and processes of a new C2 R&D program (the "how").

The workshop was held 7-9 May 96 and was organized around syndicates. The opening session provided direction from the Deputy Chief of Defence Staff (DCDS) and CRAD, as well as from a panel of senior officers and managers. The workshop then broke up into six syndicates to discuss the requirements and opportunities for C2 R&D in the areas of human factors, analytical methods, and information systems.

The syndicate process was based on a structured brainstorming technique developed by the Operational Research Division. It involved three stages: idea generation using the Nominal Group Technique; idea development using the Idea Writing Technique along with de Bono's Thinking Hats structure; and finally an anonymous vote and tally for prioritization and closure. Using this methodology hundreds of raw ideas were generated and hundreds of pages of idea development were written. All of these are recorded in the Annexes to this paper for the use of the C2 R&D Task Force in their development of a strategic plan.

In the requirements and opportunities syndicates, seven broad concepts emerged across the boundaries of the three research fields: decision support; performance measurement and evaluation; information management; information presentation; life cycle management; training; and doctrine.

Under decision support, methods of leveraging information being collected and stored in data bases were discussed to turn this raw data into good decisions. Ideas such as distributed decision making and parallel planning were discussed in relation to interoperability. Situational awareness and applications of geographic information systems were mentioned along with the use of automated acquisition of data using modern sensors. The boundary between human versus machine-dependent decision processes was identified as an area of research.

The link between the performance of C2 Information Systems (C2IS) and the force's effectiveness was emphasized under performance measurement and evaluation. The use of structured Command Post Exercises and simulations was presented as a potential solution. The idea of system vulnerability was raised and discussed. The effects of stress, fatigue, isolation, operator workload and productivity were suggested areas in which performance measurement can evaluate human performance and ergonomics.

Acquisition, access, distribution, storage and protection were identified as areas of research in information management. Ensuring the right person gets the right information at the right time is the goal; how this can be done in large systems is the question. The shelf life of data was mentioned as an issue to be resolved, as was data synchronization. It was recognized that information warfare deserves increased attention.

The avoidance of information overload is the goal in information presentation. The search for effective displays and man-machine interfaces was identified as an important area of research. The use of integrated consoles, helmet displays and virtual reality should be explored.

It was recommended that the whole system life cycle management process be streamlined and expedited for C2IS. Improved user requirements capture and evolutionary development will help. The development of Battle Labs could provide some solutions to the problems of test and evaluation. A "technology watch" needs to be set up. Interoperability, deployability, supportability and configuration management must be foremost concerns.

Improved training tailored to complex information systems is required. Wargames and simulation for training could help. Virtual reality should be investigated. Multi-media training aids should be commonplace. How much individual versus group training is required is an open question.

It was suggested that a retrospective historical review of evolving doctrine with the introduction of military technology may yield some interesting results. Issues of span of control, staff roles, depersonalization of technology and the hazard of micro-management were identified as issues for consideration under doctrine and policy.

These represent just a few of the ideas generated during the workshop. There are many others identified and described in the annexes. It is now up to the C2 R&D Task Force to evaluate these ideas and determine which should be pursued. The development of a new structure and new processes with which to carry out these research requirements and opportunities is discussed in the companion paper.

TABLE OF CONTENTS

PAGE

ABSTRACT i

EXECUTIVE SUMMARY iii

TABLE OF CONTENTS vi

ACKNOWLEDGEMENTS vii

BACKGROUND 1

THE QUESTIONS 2

THE SYNDICATE PROCESS 2

RESULTS 4
- Concept 1: Decision Support 4
- Concept 2: Performance Measurement and Evaluation 7
- Concept 3: Information Management 8
- Concept 4: Information Presentation 9
- Concept 5: System Life Cycle Management and Requirements Capture 10
- Concept 6: Training 12
- Concept 7: Doctrine and Policy 12

CONCLUDING REMARKS 14

REFERENCES 15

ANNEX A - SYNDICATE 1A: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN HUMAN FACTORS FOR COMMAND AND CONTROL A-1

ANNEX B - SYNDICATE 1B: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN HUMAN FACTORS FOR COMMAND AND CONTROL B-1

ANNEX C - SYNDICATE 1C: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN ANALYTICAL METHODS FOR COMMAND AND CONTROL C-1

ANNEX D - SYNDICATE 1D: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN ANALYTICAL METHODS FOR COMMAND AND CONTROL D-1

ANNEX E - SYNDICATE 1E: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN INFORMATION SYSTEMS FOR COMMAND AND CONTROL E-1

ANNEX F - SYNDICATE 1F: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN INFORMATION SYSTEMS FOR COMMAND AND CONTROL F-1

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CRAD COMMAND AND CONTROL WORKSHOP: REQUIREMENTS AND OPPORTUNITIES FOR C2 R&D

BACKGROUND

1. The Chief of Research and Development (CRAD) directed that a high-level study be conducted into Command and Control Research and Development (C2 R&D) in the Department of National Defence (DND) [1]. As part of this study, a workshop was organized to bring together Canadian Forces (CF) Officers and CRAD scientists to discuss the "what" and the "how" of C2 R&D. Approximately 30 scientists and 30 Officers were divided equally into six syndicates. These worked for two days to develop the ideas from which a strategy for C2 R&D could be developed by CRAD in conjunction with the leaders of the CF and DND. The following paper discusses the results of the first day of deliberations, on the requirements and opportunities for C2 R&D (the "what"). A companion paper discusses the structures and processes to carry out an effective C2 R&D program (the "how") [2].

2. The workshop began with a plenary session in which the Deputy Chief of Defence Staff (DCDS) and CRAD gave statements providing direction to the attendees. This was followed by presentations from a panel of senior officers and civilian managers that provided additional direction and scope. The workshop then broke into six syndicates to discuss the requirements and opportunities for C2 R&D in the areas of human factors, analytical methods, and information systems. When the workshop reconvened the next day, the syndicate facilitators presented a summary of their findings to the plenary. The workshop then reorganized into new syndicates to discuss the structures and processes required to deliver this C2 R&D. On the morning of the final day, a panel of senior officers and managers convened to hear summary presentations of the previous day's syndicate results. The following paper provides a consolidated overview of the presentation on the first syndicate session on requirements and opportunities for C2 R&D. The detailed work of the six syndicates is provided in the Annexes.

THE QUESTIONS

3. The first syndicate session addressed the "what" of C2 R&D. Since this question is very broad, it was divided into three focal areas, addressing human factors, analytical methods (including operational research and systems analysis), and information technology issues. The following three questions were examined by the syndicates:

a. Syndicates A, B: "What human factors R&D is required and what opportunities does it provide, to support the CF in its command function?"

b. Syndicates C, D: "What operational research and systems analysis are required and what opportunities do they provide, to support the CF during the complete life cycle of C2IS?"

c. Syndicates E, F: "What R&D in information systems and information technology is required and what opportunities does it provide to support the CF during the complete life cycle of C2IS?"

4. The groups were given the opportunity to discuss these questions for clarification. The idea generation exercise would not initially consider feasibility, costs, and benefits. These concerns would be addressed to some degree in the second part of the exercise involving idea development and the second syndicate session on how to structure and carry out an effective R&D program. In order to facilitate discussions on the above questions, a structured process was used.

THE SYNDICATE PROCESS

5. A structured brainstorming approach [3,4] was used in the syndicate deliberations to maximize the effectiveness and efficiency of the process. Syndicate Session One was divided into six groups. Two groups addressed each of the questions stated above. This process was conducted in three stages with multiple sub-stages:

a. the idea generation stage (using the nominal group technique):

(1) discussion of the problem statement to obtain focus;

(2) individual silent idea writing for raw idea generation;

(3) round-robin collection of the ideas; and

(4) grouping of ideas around concepts;

b. the idea development stage using deBono's Thinking Hats [4]:

(1) prerequisites in terms of information needs;

(2) how-to's in terms of creative implementation approaches;

(3) benefits of progressing this initiative;

(4) possible negative effects or potential problems with implementation;

(5) bottom-line unsubstantiated "gut feeling" about the concept;

c. prioritization:

(1) anonymous vote and tally; and

(2) discussion of results of the vote.

6. This process was developed to improve productivity and to encourage creativity in group discussions. It was intended to get a lot of work done in the time available and yet be egalitarian and non-confrontational. It attempted to drive to a consensus in the group yet allowed for dissenting opinions in the anonymous vote thus avoiding "group think". It was intended to be self-documenting. It used low technology equipment and was therefore inexpensive to conduct. It was structured so that it was nearly facilitator free, and training of the facilitators was not time-consuming or expensive.

7. The process generated hundreds of raw ideas that were suggested by the participants in good faith to enable the development of new Command and Control Systems for the CF. During the idea development process, over one hundred pages of notes were generated. All of this information is provided in the Annexes to this report. Unfortunately, when the

presentation to the panel was provided, there was insufficient time available to do a complete analysis of the detailed information. It is hoped that the C2 Task Force will have time to evaluate the material in full detail in time to complete their report. The following discussion of the syndicates' findings represents a synopsis of the ideas generated. There was a high degree of commonality among the syndicate groups working in parallel.

RESULTS

8. The first syndicate session generated 264 ideas that were then grouped into categories by individual syndicates. A large amount of overlap was seen in the results addressing R&D requirements for human factors, analytical methods and information. These ideas were brought together into a unified framework for this report. Emerging themes were established, forming seven broad domains or concepts.

9. For each concept, specific research problems and areas were classified according to their applicability to human factors (HF), operational research and systems analysis (OR/SA), and information systems and information technology (IS/IT). Many of the R&D areas proposed by syndicate participants were common across several research fields. The seven concepts representing groupings of syndicate categories are shown in Table I below.

10. The concepts are presented in a rough order of priority. Combining priorities for the workshop as a whole was problematic. It is difficult to prioritize all of the concepts strictly, as the groups developed different proposals with varying degree of overlap. The object of the exercise was to explore the breadth of R&D that could be done, therefore a large number of ideas was expected. A subjective ranking based on the popularity of the ideas and individual group priorities is given in Table I. Syndicate categories were grouped into concepts by the authors. Numbers denote each syndicate's priority ranking. Ties are allowed: syndicates were permitted to assign equal priority to two or more categories.

Concept 1: Decision Support

11. The first concept that emerged as very important is that of decision support. This concept covered many individual ideas. Without adequate decision support tools, C2 systems become large and complex data repositories containing much of the information needed to make good decisions. How to best leverage this information by developing decision support tools clearly needs to be explored. The OR/SA syndicates did not list Decision Support as

a separate category, but examination of the syndicate's ideas shows it to be an unnamed theme throughout.

TABLE I
SYNDICATE SESSION ONE CATEGORY/CONCEPT SUMMARY AND PRIORITIES

		Number of Ideas:	58	37	36	32	46	55
					Syndicate			
			HF	HF	OR/SA	OR/SA	IS/IT	IS/IT
	Concept	Syndicate Category	A	B	C	D	E	F
I	Decision Support	Decision Support	2	1				1
		Automated Decision Aids/Fusion					2	
II	Performance Measurement and Evaluation	Human/System Performance	4		1			
		Performance Measurement		1				
		Feedback			1			
		Evaluation Methods				1		
		Operational Evaluation			4			
III	Information Management	Information Access	3					
		Data Distribution						3
		Information Management					1	
		C2 Warfare					1	
		Security						5
		Data Acquisition/Fusion						1
		Knowledge Engineering	7		3			
		Knowledge Elicitation		6				
IV	Information Presentation	Information Presentation	1					
		User Interface		2				
		Person-Machine Interface						2
V	Life Cycle Management	Life Cycle Process Modification			2			
		Requirements Capture			1	2		
		Information Requirements					3	
		System Design/Build				3	4	
		Architecture						4
		Standards						5
		System Integration					4	
		System Acquisition						6
		Fielding			1			
VI	Training	Training	5	3				
		Support						5
VII	Doctrine	Doctrine				4		
		Teamwork	6	4				
		Leadership		5				

12. Many individual research areas fell under this concept. With new C2IS systems with improved high speed connectivity, the idea of collaborative and distributed decision making may hold promise. The traditional concepts of teamwork might be transformed. Team dynamics and personality factors affecting decision making might be studied. The development of new techniques for parallel planning to exploit teams having access to a common knowledge base might be researched. The issue of interoperability needs to be addressed in this context. IS/IT will need to investigate technologies to enable collaborative work to be done over networks, including 'blackboard' applications and real-time video conferencing. Distributed computing may link several users together working collaboratively on individual sub-tasks.

13. Situational awareness and the development of a recognised tactical picture are vital elements to many C2IS. Further research into the application of GIS and map viewers could unlock this potential.

14. Several human factors issues such as decision-making under stress, time pressure, and physical isolation were proposed. In turn, the operator must understand the limits of the system and its ability to provide decision support. What level of processing is best left to the machine as opposed to the operator? For example, in the area of sonar processing powerful systems have greatly extended the operator's capabilities. Where to 'draw the line' for each task is yet unclear.

15. Libraries of mission planning tools will be needed to supplement C2IS, supporting individual functions from surveillance, air operations, and specialised areas such as under-water warfare. It was proposed that OR/SA and IS/IT examine applications of heuristics and optimization in resource allocation, forecasting, and control. Applications could employ fuzzy logic, data mining and filtering, expert systems, and neural networks. Knowledge to build knowledge bases for specific operations may enhance control functions. For computer-intensive tasks, adaptive systems could produce the best solution in the time available.

16. For improved decision support, IS must achieve better methods of automated data acquisition from a variety of sensors. Systems should not be limited by labour-intensive manual data entry. Interoperability is important in decision support since the CF must be able to share jointly within the CF and with its allies.

17. Given data streams from several independent sources, methods of fusing data and consolidating it into a single coherent entity must be developed for decision support systems. Belief management and data source tracking were suggested as avenues for investigation.

Concept 2: Performance Measurement and Evaluation

18. Performance measurement and evaluation apply to system operators and physical systems, as well as to the infrastructure linking these elements together. Given well-developed decision aids, how can we assure that C2 systems are performing at acceptable levels? There is a requirement to develop methods of assessing the performance of C2 systems.

19. It was proposed that all three fields must develop a framework in which operators and machines as components of C2IS can be quantitatively evaluated. First generation systems can be evaluated for their shortfalls in addressing C2 requirements. Once evaluation methods are agreed, some Measure of Performance (MOP) and Measure of Effectiveness (MOE) hierarchies must be developed to quantify C2IS performance. One objective could be to link the performance of C2IS with force effectiveness. The use of structured Command Post Exercises (CPX) and simulations could collect necessary data. Systems might be put in place to carry out real-time performance monitoring for operational systems. In doing this, an objective assessment of system limits could be established.

20. The idea of system vulnerability was raised and discussed. Good features of C2IS include graceful degradation from individual component failures, a limited number of well-understood failure modes, and scalability with increased number of users and data flow. IS/IT will need to examine system performance requirements both from a hardware and software perspective. IS/IT might examine developments of parallel processing to address limits of individual CPU power.

21. Specific human factors research for evaluating the performance of system operators might examine motivation, the effects of Man-Machine Interface (MMI), and ergonomics on performance. The subjective area of operator problem-solving effectiveness when facing a particular scenario could be addressed by some measure of quality of control and decisions made in time. The effects of fatigue, stress, and isolation on operator workload and productivity were suggested.

Concept 3: Information Management

22. Information management encompasses all aspects of information handling: acquisition, access and distribution, storage, security, and protection given the vast amount of information collected by C2IS. Data management tools and techniques must be in place to support uninterrupted operations.

23. At the outset, information requirements must be clearly defined so that the right person gets the information he or she needs at the right time in order to carry out his or her particular function. Data flow modelling to support information sharing including joint operations is long overdue. OR/SA must be able to represent current and future data flows accurately for both domestic and deployed operations. Information required at the strategic, operational and tactical levels must be identified.

24. Most C2IS do not function in isolation, so the scope and connectivity of each system must be defined. The utility of information must be matched to the cost of data collection. Some research should be done to identify what information is available today, and what will be possible in the future as part of C2IS. Critical information paths must be identified, acceptable transmission delays developed.

25. New means of information acquisition must be put in place to support C2IS. This might be achieved through new sensors and relay systems, such as aircraft position tracking systems. With the foreseeable volume of C2 data, methods of data storage, archiving, and management must be put in place. World-wide R&D into data compression techniques for voice, graphics, and video has made significant progress in recent years.

26. IS/IT might explore the use of smart systems, such as agent-based programs, to manage information pull from various sources and to satisfy reporting requirements. Information sharing standards must be developed among services. Standard data exchange formats must allow for improved interoperability.

27. Spatial and temporal database management techniques will need to be developed in order to manage the wealth of time-based data collected by C2IS.

28. Data has a shelf life. Once it has been obtained, its accuracy cannot be maintained indefinitely without maintenance. The varied requirements for data regeneration must be examined.

29. OR/SA must look at a Joint Forces data model to support data flows. Several levels of integration can be foreseen, from total forces-wide integration into a single data model, to individual service data models that are compatible. The best approach is as yet unclear.

30. IS/IT should examine database synchronization for information replication and distributed databases. The connectivity required to support information management properly should be examined. It was mentioned that no clear direction on bandwidth has been developed for many CF systems.

31. C2 Warfare or Information Warfare (IW) deserves increased attention. It is a relatively new concept to which the US is allocating significant resources (Reference 5). Information protection through the use of firewalls and cryptography probably needs to be expanded in a world of open systems architectures. Counter-measures and counter-counter-measures of would-be infiltrators must be studied, since a vast majority of corporate and operational data will conceivably reside in C2 information systems.

Concept 4: Information Presentation

32. C2IS must do more than acquire and manage information. It must be presented to the user in a meaningful way.

33. There is a large body of research on effective data presentation, including the use of colour, motion, sound, and multi-dimensional representations. The specific application of this research to C2IS may involve any or all of HF, OR/SA, and IS/IT. The effectiveness of presentation methods could be explored. Novel uses of virtual reality were suggested as a way of representing patterns in multi-dimensional data.

34. All three fields noted man-machine interface (MMI) as an important area to study. Specific to HF, system ergonomics must be built in to C2 systems. It is unclear if research to date has addressed all areas. HF experts must address the problem of perception and the threshold of information overload.

35. In order for the vast amount of information provided by C2IS to be useful to the operator, it must be summarized and often filtered. One problem for OR/SA in this regard is the problem of decision aids. R&D should continue in the area of GIS and geomatics. The ability of a commander to pull up a real-time situation map is not in the field yet.

36. IS/IT might explore new display technologies such as integrated consoles and helmet displays. The effectiveness and limitations of present input/output devices should be well understood.

37. Standardization across systems and environments must occur. Standard information presentation and interfaces could reduce training requirements and improve operator proficiency. It would likely facilitate system development and maintenance for the CF.

Concept 5: System Life Cycle Management and Requirements Capture

38. The whole area of system life cycle management must be addressed. This requirements capture, systems design, prototyping and development, acquisition, fielding, and support. All must be addressed if the CF is to get a return on its investment in C2IS. Risk analysis and cost-benefit analysis may allow the CF to better deliver capabilities to the field on time and on target.

39. Several syndicates recommended that the complete life cycle management process for IT projects be streamlined and expedited. With the rapid pace of technology, IT projects cannot be managed under the same procedures as main equipment procurement projects. Flexibility and evolution must be built into the process. Simulation might be used in order to demonstrate the feasibility of new C2IS. OR/SA might be able to provide assistance in quantifying payback in terms of improved efficiency and effectiveness.

40. All three fields of HF, OR/SA, and IS/IT must develop improved methods for user requirement elicitation and capture. Once initial user requirements have been stated, requirements management must be addressed in an environment of evolutionary system development. Computer assisted software engineering tools may help in this area. 'Endless cycles' of evolutionary capability development were favoured to the large 'do-all' systems delivery approach.

41. The development and increased use of system testbeds or 'battle labs' was recommended by most groups. Battle labs were seen as much more than a series of interconnected prototypes. They also involve the planning of exercises and evaluation of tools in order to test them and measure and confirm user requirements in a realistic operational environment. The idea of the user as developer and the developer as user suggests a much closer working relationship among the CF and scientific communities if C2IS are to address the critical functions.

42. CRAD could put in place some form of systematic "technology watch" in order to anticipate technological innovation and to evaluate its impact on R&D plans. Within the evolutionary systems development approach, systematic field trials must be planned and carried out in order to better address user needs at all levels.

43. Interoperability standards must be developed in order to support joint and combined operations from the strategic to the operational and tactical levels. There must be lateral interoperability, not simply vertical stove-pipes. IS/IT must identify networking capabilities.

44. System deployability, too often addressed as an afterthought, must be built into development plans. Research in this area would allow proper system architectures to support the CF in the field as required. Strategies such as miniaturization and ruggedization are but a few that may support deployability in this context. Requirements for connectivity either through networking or wireless must be identified and technological solutions found.

45. A CF-wide functional analysis survey of information systems is required in order to properly understand the relationships that exist among information and command and control systems. Within a given area, operator job functions must also be analyzed. Workload balance among staff organizations is required.

46. It was recommended that CRAD investigate the cost and feasibility of adapting commercial, government, and military off-the-shelf (COTS/GOTS/MOTS) systems for the CF.

47. There needs to be R&D into alternative system architectures. Systems must be not only technologically feasible but also supportable. The re-use of software libraries, for such things as user interface elements, could save money and improve supportability. Configuration management of large C2IS must be addressed. There must be further

development of standards and procedures for rapidly evolving systems in order to be able to maintain them over the complete life cycle.

Concept 6: Training

8. Training was raised by several groups. Improved methods and practices for training in the area of C2IS must be developed. Training tailored for complex information systems may be required to ensure operator proficiency. The field of HF could examine mental models, reinforcement, and learning in order to achieve better training value for time spent. OR/SA could help in the application of wargames and simulation for training as well as scenario development. Recent developments in virtual reality might have applications to training for military C2 systems.

49. Training programs for C2IS may be facilitated by using multi-media training aids. For example, PC based multi-media training aids are already being used to supplement flight engineer training for complex transport aircraft engine systems. In order to maintain adequate support for deployed C2IS systems, it may be useful to explore ways of providing remote help and distance support to users in the field.

50. It was proposed that CRAD study the benefits of group versus individual training effectiveness. What reinforcement will be required for operators working with complex C2IS? Should systems be adaptable to the ability level of the operator, or should all functions be available to all operators, whether they can use them effectively or not? Much data could be collected as part of training exercises on C2IS systems. Measures of performance and measures of effectiveness for training could be developed.

Concept 7: Doctrine and Policy

51. Many of the ideas raised by the syndicate groups could be classified under the concept of doctrine. This is not to say that CRAD should pursue a research program in doctrine and IS policy. Rather it is an acknowledgement that CF members must be involved at all levels of C2IS development, from inception to design, fielding, and support. An evolving CF doctrine will play a vital role in enabling the development, implementation, and acceptance of modern C2IS. New ways of controlling operations may need to be developed in a modern world of high-speed networks and connectivity from the battlefield to the military headquarters. It is well accepted that C2 systems should support and be driven in large part

by doctrine and concept of operations. There is also the reverse view where IS/IT may have a positive impact on the evolution of doctrine by enabling new possibilities in terms of communications and force co-ordination and control. Minor realignments in the concept of operations may unlock the potential of C2IS. A retrospective historical review and evaluation of evolving doctrine with the introduction of military technology may yield insights.

52. A large number of ideas were raised related to doctrine. Span of control and measures of effective control as supported by C2IS must be defined. Concerns were raised about the transformation of leadership in an automated world. Again the area of team dynamics, collaborative decision making, and parallel planning may be affected by C2IS. Associated communications problems were foreseen, such as how to convey nuances, criticism, and non-verbal communication and its impact on decision making. These concerns may lead to requirements for not only single workstation operator training but also co-ordination training, since personal interactions are important.

53. OR/SA may be able to assist in mapping processes currently used within the CF and DND in order to ensure that systems are better able to support peacetime business processes and operations as well as deployed wartime functions. Staff roles may need to be redefined with the advent of C2IS, automating many labour-intensive tasks. Command structures may need to be re-aligned with technology. There were clearly different views as to the best approach of an information pull system vice a push system. Information sharing, data security, and availability were issues that were raised. In a world of increased message and data traffic, how do we prioritize data transfers vying for limited bandwidth, by urgency, importance, or some combination of both?

54. Concerns were raised about the depersonalization of systems, and micromanagement due to technology. The IS/IT community through some form of systematic technology watch may be able to foresee potential new applications and stimulate the development of revised doctrine and concepts of operations. The vision of commanders at all levels working from a common tactical map breaks down many traditional barriers to effective military command and control.

55. It was recommended that CRAD keep a close watch on what our allies are doing in this area, so as not to repeat hard lessons learned in automating systems. Guidance from commanders on how far to go in automated decision making, what to automate, semi-automate or leave alone will need to be given. Our C2IS systems must be able to address CF

needs for a whole spectrum of operations, from everyday peacetime operations and training, to peacekeeping, to low, medium and high intensity conflicts.

56. Finally but not the least important is the concern of security. Imposed security constraints may limit what information can be shared by units. Will C2IS be able to operate when some systems are down or engaged?

CONCLUDING REMARKS

57. The annexes to this report provide the detailed results of each of the syndicates for future reference. The R&D areas discussed were elicited in an open, creative and informal manner. It was not the objective of the workshop to develop a feasible co-ordinated research program for all these research areas. Rather, the result of this session provides valuable input to CRAD to build a revised strategic direction for C2 R&D.

58. All proposed research areas must be prioritized and assessed as to whether they are feasible, and what would be the payoff and risks for the CF and DND. Some areas may not be mature enough, others may have been studied at length and all that is required is the application of this research to C2.

59. In summary, the workshop achieved its objective in bringing together technical subject matter experts and CF members from all communities in a joint forum for discussion. Most participants felt this exercise was worthwhile. Further detailed analysis and prioritization of these results by the C2 R&D Task Force is required.

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[4] Taylor, Ivan, *An Extension to Structured Brainstorming Using the Six Thinking Hats*, DLogA Research Note 9604, April 1996.

[5] *Pentagon Debates Potential of Information Warfare*, Defence News, Vol. 11 No. 19, May 13-19 1996.

SYNDICATE 1A: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN HUMAN FACTORS FOR COMMAND AND CONTROL

INTRODUCTION

A-1. Syndicate 1A was asked the following question:

"What human factors R&D is required and what opportunities does it provide, to support the CF in its Command and Control functions?"

This syndicate went through the process of Idea Generation and Concept Grouping, then Concept Development and Prioritisation. The syndicate developed 53 ideas which were grouped into the following eight concepts:

a. Presentation of information;

b. Information access (push vs. pull);

c. Decision support;

d. Human performance;

e. Evaluating performance;

f. Training;

g. Knowledge engineering; and

h. Teamwork.

A-2. The following format is used in documentation. For each concept:

a. Idea base for each concept (generated via Nominal Group Technique);

b. Idea development for each concept (generated via Six Thinking Hats):

(1) Information needs;

(2) Creative solutions;

(3) Benefits;

(4) Problems; and

(5) Gut feelings;

c. Prioritization (anonymous syndicate member votes).

A-3. Voting results were tabulated. Results and average ranks appear at the end of this annex. This syndicate assessed concepts in the following approximate order of priority:

a. Decision support (Concept C);

b. Presentation of information (Concept A);

c. Information access (Concept B);

d. Training (Concept F);

e. Human performance (Concept D);

f. Evaluation performance (Concept E);

g. Knowledge engineering (Concept G); and

h. Teamwork (Concept H).

IDEA INVENTORY

1. Capability to absorb information
2. Development of Command doctrine that will benefit from automated C2IS
3. Display technology
4. Data presentation
5. Information fusion
6. Develop a theory of Command - what it is / how it works?
7. Get right information to right person at the right time
8. Ergonomics
9. Can system be customised?
10. Automation of push-pull access to information
11. Helping people come to decisions
12. Wargaming real-time
13. Redefining staff roles
14. Team dynamics and decision making
15. Collecting information for real world operations
16. Dissemination
17. Heuristics
18. Explanation based systems
19. Environmental knowledge, forecasting and control
20. Information mining
21. Situation awareness
22. Collecting information from structured exercises
23. Effect of human fatigue - can a machine cover for it?
24. Realistic training on the C2IS to practice C2 process using scenario simulation
25. Effective control (clear, understandable)
26. Integrated console/helmet technology
27. Confirming requirements through evaluation with real users
28. Making the system sailor-proof
29. Tailoring foreign C2IS to Canadian requirements
30. Parallel planning. Real-time co-authorship
31. Measures of performance effectiveness
32. How does C2IS support Force effectiveness? How can it be measured?
33. Ability to exploit our small community to work together better
34. Security and sharing information
35. Reducing uncertainty through expert systems

36. Distributed decision making
37. Domain knowledge engineering
38. Neural networks for decision making
39. Tension between time and uncertainty in decision making
40. Total system integration
41. Use of holographic images
42. Non-verbal communication. How important is it in decision-making and teamwork?
43. Confidence in information
44. Reliability of information
45. Fuzzy logic
46. Effects of isolation
47. Fragility of information units
48. Span of control
49. How the human determines what information pool is available?
50. Effects of stress (all sorts)
51. Motivation
52. Post-traumatic shock
53. Flexibility in control systems
54. Short-term drug enhancement
55. System adaptable to user capability
56. Ability of commander to directly impact
57. Personality factors that influence decision-making
58. How a person understands what the limit of a system are?

CONCEPT A: PRESENTATION OF INFORMATION

1. Capability to absorb information
3. Display technology
4. Data presentation
7. Get right information to right person at right time - What is right?
8. Ergonomics
9. Can system be customised
11. Helping people come to decisions
16. Dissemination
19. Environmental knowledge, forecasting and control
21. Situation awareness
26. Integrated console/helmet technology
28. Making the system sailor proof
30. Parallel planning. Real-time co-authorship
34. Security and sharing information
36. Distributed decision making
38. Neural networks for decision making

40. Total system integration
41. Use of holographic images
42. Non-verbal communication. How important is it in decision making and teamwork?
49. How the human determines what information pool is available?
55. System adaptable to user capability
56. Ability of commander directly impact

Presentation of information: Information Needs

1. Info must be clear, colour coded
2. Be of the same standard (joint/combined/canus/....stanag).
3. Static displays vice "movie" (dynamic)
4. Colour symbology
5. How much/screen; how many screens
6. What is the relative benefit of information presented in different modalities (e.g. Audio, tactile)
7. What is benefit of multi-modal presentation
8. Screen technology
9. What is current state of art
10. What is required in 10 years
11. What is reliability of info
12. How much can I/my staff absorb
13. How easily can I change the presentation
14. Impact of other senses than visual
15. How can temporal (time) data be displayed (i.e. Tracks)
16. Display of RF spectrums
17. Importance of more than 1 sensory input
18. Customization of info to present to individuals

Presentation of information: New ideas and possibilities

1. Audio-visual multi-media, presentations
2. Video teleconferencing / command deployments on the spot
3. Explore the training of improvement of presentation techniques (e.g. briefings etc.)
4. Desk top video/multimedia
5. Use of large screen, MUD technology
6. Rapid prototypes
7. Feed directly to brain
8. Use multiple human sensors at same time (sight, hearing, smell, touch)
9. Use of 3d images holographs
10. Use of sound and smell to enhance the message

11. Interactive access to data base info by selection objects on screen
12. In consort with allies agree/develop geographical & intelligence data base
13. Be like a Klingon Battle display - a tabletop hologram of the battlefield

Presentation of information: Benefits

1. C2 is impossible without effective information presentation
2. Better presentation will reduce time for decision making and accuracy
3. Enhanced ability to assimilate info
4. Personalized systems would enhance buy-in
5. Improve quality of decision
6. Better quicker understanding of the real situation
7. Better able to make good fast decisions
8. Enable new ways to compute complex information
9. Ensure common specification & quicken loop
10. Widely display info so that entire team can aid in the decision cycle
11. Reduce personnel
12. Innovative solutions may appear

Presentation of information: Problems

1. No real benefit has been demonstrated to date
2. Technology is limiting factor
3. User buy-in is difficult
4. Vulnerable to C2W attack
5. User forgets info reliability issue
6. Computational expense
7. Every week there is a better display which the user wants, so no continuity is developed
8. Too many choices, different preferences
9. Training requirements may be expensive keep it simple
10. User's are familiar with PCS
11. Difficult to agree to standards (coalition concerns)
12. Would be expensive to buy & maintain
13. Equipment/computer dependant(no power, no C2 system, can't fight the war)
14. Presentation is individualistic - do we need virtual reality?

Presentation of information: Gut Feeling

1. Vital
2. Great
3. Most important to start here

4. Keep it simple
5. Must be clear
6. Vital - its how the good decisions will be made
7. Essential
8. Boring; more important problems

CONCEPT B: INFORMATION ACCESS (PUSH vs. PULL)

7. Get right information to right person at the right time
9. Can system be customised?
10. Automation of push-pull access to information
11. Helping people come to decisions
15. Collecting information for real world operations
16. Dissemination
19. Environmental knowledge, forecasting and control
20. Information mining
21. Situation awareness
28. Making the system sailor-proof
34. Security and sharing information
38. Neural networks for decision making
40. Total system integration
43. Confidence in information
48. Span of control
49. How the human determines what information pool is available?
53. Flexibility in control systems

Information Access: Information Needs

1. Current systems at NDOC, AIRCOM, LFC
2. Info we know, info we need, how do we get it?
3. Who should have access, multi-level security
4. S/W to access data base
5. How to close system down if node captured
6. Structure of data base
7. How do humans structure information?
8. How can systems make their structures known?
9. What info is avail
10. How do we constrain demand for tactical ops
11. Knowledge of web technology for pull
12. Structured/non-structured info
13. What info is relevant to my current situation
14. What filters are available to process data
15. How does commander's staff operate?

16. How is incoming info categorized as important

Information Access: Creative solutions

1. Identify, automatically, critical info which must be actioned immediately, in 5 min, in 1 hr etc.
2. Explore trunk-tank approached to accessing info from other team members
3. Fast prototyping
4. Use web technology TCP/IP, OSI, OS protocols
5. Demonstrate one exercise
6. Integrate into ops
7. Machine advice on pull (tech push, operator pull)
8. Maintain data base at many nodes
9. Ask machine for info
10. Identify yourself to machine by voice/fingerprint etc. Perhaps more than 1
11. Machine learning of individual user's habits, usual interests, most searched for information, etc. And automatically push info to user
12. Mine experts to determine inter-reliability of info
13. Must be distributed

Information Access: Benefits

1. Improved access/performance
2. Leverage on commercial internet/surfing
3. Avoid info overload
4. Avoid comm system overload
5. Allow more people to participate
6. Enable commander to react quicker to Battlefield units
7. Keep soldier in the loop
8. Reduce redundancy & perhaps manning requirements
9. Support precision guided munitions
10. Support customization
11. Reduces reaction time
12. Report to politicians with timely/accurate info (not pre-empted/surprised by CNN)
13. Assists situation & battlefield awareness
14. Reduces uncertainty

Information Access: Problems

1. Important info may be missed
2. Don't have bandwidth
3. Info overload

4. Vulnerable to C2W i.e. Security risk
5. Unintentional access to info could have unforeseen bad consequences
6. "Need to know" principle easily broken
7. How do you pull info you don't know about?
8. Who decides what info to push?
9. Info may be fragile-will it be sailor/soldier proof?
10. Verify/authenticate/authority sender-receiver (security dimensions common problems)
11. Requirements for large data sets in studies in this area
12. Too many security obstacles
13. Technology for MLS/gateways not adequate

Information Access: Gut feeling

1. Essential
2. Critical
3. Dangerous
4. Can't live without it, difficult to live with it
5. Must be limited somehow (too easy to attack) yes but who needs it? When? How to ensure security?
6. Potentially overwhelming
7. Needs a lot of work.

CONCEPT C: DECISION SUPPORT

5. Information fusion
7. Get right information to right person at the right time
9. Can system be customised?
11. Helping people come to decisions
12. Wargaming real-time
14. Team dynamics and decision making
16. Dissemination
18. Explanation based systems
19. Environmental knowledge, forecasting and control
21. Situation awareness
25. Effective control (clear, understandable)
28. Making the system sailor-proof
30. Parallel planning. Real-time co-authorship
32. How does C2IS support Force effectiveness? How can it be measured?
35. Reducing uncertainty through expert systems
36. Distributed decision making
38. Neural networks for decision making
39. Tension between time and uncertainty in decision making

40. Total system integration
41. Use of holographic images
43. Confidence in information
44. Reliability of information
45. Fuzzy logic
48. Span of control
55. System adaptable to user capability
56. Ability of commander directly impact
57. Personality factors that influence decision-making

Decision Support: Information needs

1. What decision aids are available
2. How do military Cdrs. make decisions
3. What reliability of aids is required for confident use
4. Theories of decision making
5. Current systems available
6. Studies of staff systems-info needs of staff
7. Outcome of each possible solution
8. Resources required for each possible solution
9. Comparison of what led to good/bad decision
10. Measurement of confidence/reliability of incoming info and resulting output decisions.
11. Can Wargaming be done in enough time to permit proper near real time optimization analysis vs. pre programming
12. Must be a 'camp fire' approach to effect a check-balanced system for decision making
13. S/W DSS from allies/current

Decision Support: New ideas and possibilities

1. Prototype expert system
2. Iterative user trials
3. Use joint staff/op HQ as site
4. Integrate into training cycle of commands
5. Have scientist attached to each site
6. Remove human from loop as much as possible
7. Have system produce options for commanders to choose
8. Measure and define quantitatively performance of system with different users against simulation exercise
9. Liaise with allies/industry
10. Use a table top display which enhances human interaction in decision making process

11. Put human back in loop and compare results keep track of options, simulate alternatives
12. Explore validity of naturalistic decision theory for CF

Decision Support: Benefits

1. Training
2. Bit by bit (gradual introduction)
3. Better decision will let us better achieve our goals
4. Reduce human error (all factors consistent)
5. Provide means of tracking decision process (who decides what)
6. Ensure timely decisions
7. Ensure direction well articulated/understood
8. Reduces the fog of war
9. Makes info easier to take in
10. Not as dependent on personality of commander looks the same - anyone can use it
11. Decision making is the heart of C2 support is critical
12. Prove worth by assisting staff and command in real terms

Decision Support: Problems

1. Do not help all people and may hinder certain leader's decision style
2. Can't be comprehensive enough to cover everything, could leave out critical info
3. May lead to too much reliance on it
4. How much do you automate? What do you leave manual?
5. How do you process incomplete information into a decision, machines have no "gut-feel"
6. Must avoid being too predictable
7. Difficult to win over user's confidence
8. Might become too dependant upon computer system when it fails what do you do?
9. Can't replace human decision maker; will not trust a machine with 'big' decisions
10. Danger of over-automation humans are still responsible for decisions
11. Danger of decision aid "looking on problems to solve"
12. Few, if any, true expert systems available
13. Reluctance to accept "systems" answer/advice
14. Lack of confidence in machine input
15. Loss of manual method

Decision Support: Gut feeling

1. Good stuff
2. Lots of R&D required
3. Vital given information available & time constraints
4. Most important
5. Key but needs lots of work
6. A core need
7. The way ahead
8. Must not become over dependent

CONCEPT D: HUMAN PERFORMANCE

1. Capability to absorb information
8. Ergonomics
9. Can system be customised?
21. Situation awareness
23. Effect of human fatigue - can machine cover for it?
26. Integrated console/helmet technology
28. Making the system sailor-proof
41. Use of holographic images
46. Effects of isolation
48. Span of control
50. Effects of stress (all sorts)
51. Motivation
52. Post-traumatic shock
54. Short-term drug enhancement

Human Performance: Information needs

1. Need - baseline human performance
2. Establish how to measure effectiveness
3. Establish goals or targets
4. Variability by stress
5. Evaluate training methods
6. Results of how people perform under new/different conditions
7. Improving performance drugs to enhance performance
8. Sleep deprivation on cognitive skills
9. Limits on human abilities
10. Have - documented battle fatigue stress medical research
11. User effectiveness in performing C2 IS function with and without automated C2IS system
12. Need for baseline education etc.

13. The ergonomics of stress (seating, posture, mental agility after not sleep etc.)
14. Measurement of creativity
15. Measurement of flexibility
16. Assessment of range of human performance.

Human Performance: New ideas and possibilities

1. Ensure everyone gets the right amount of stress for maximum performance e.g. A pill perhaps
2. Try and duplicate op environments everywhere for maximum performance
3. Slot people very carefully into jobs they will be best at
4. Maintain detailed records of each user performance using C2IS during simulated war game - real world ops
5. Build stress into exercises
6. Develop measures to evaluate individual strengths/weaknesses
7. Develop system hardware to ensure that ergonomics of human interaction is measured
8. Degrade systems (controlled) during exercise
9. Expand the set of tasks used to measure human performance
10. Build in medical research
11. Field trials
12. Built in tests
13. Machine assist

Human Performance: Benefits

1. Will make user happier and more effective in their duties
2. Will identify deficiencies in system
3. Will identify new requirements in system
4. Enhance human performance (by doing the 'right thing')
5. Identify those to be appointed in Command
6. Guidance for recruiting
7. Lessen stress & optimize decision making process
8. Few people required
9. Human is key to C2 human has responsibility
10. Support the human element in combat systems
11. Makes up for equipment deficiencies

Human Performance: Problems

1. Does it make for individualism easily
2. Difficult to establish meaning

3. Putting people under stress (during training scenarios) can only be done for a limited time (does it really inoculate them from real stress when it occurs?)
4. Metrics are very difficult to define, measurements are suspect & hard to validate
5. Human variability and adaptability are confounding factors
6. Therefore large subject pools needed for studies
7. Some options/drugs simply not avail in Canada
8. Human rights
9. Difficult to measure on complex tasks
10. Too complex
11. How to measure day to day variability
12. Using common sense would be better use of resources than exhaustive study in an area that has only marginal benefit
13. Are measurements useful? Who uses them?

Human Performance: Gut Feeling

1. Important enabler
2. Hard to quantify
3. Essential
4. Baseline
5. Hard to do
6. Little improvement possible
7. Hard to rate significance
8. How does machine effect it?

CONCEPT E: EVALUATING PERFORMANCE

9. Can system be customised?
22. Collecting information from structured exercises
23. Effect of human fatigue - can machine cover for it?
24. Realistic training on the C2IS to practice C2 process using scenario simulation
27. Confirming requirements through evaluation with real users
28. Making the system sailor-proof
29. Tailoring foreign C2IS to Canadian requirements
31. Measures of performance effectiveness
32. How does C2IS support Force effectiveness. How can it be measured?
39. Tension between time and uncertainty in decision making
43. Confidence in information
44. Reliability of information
46. Effects of isolation

47. Fragility of information units
53. Flexibility in control systems
54. Short-term drug enhancement
58. How a person understands what the limit of a system are?

Evaluating Performance: Information needs

1. Test results
2. Maximum performance levels
3. Standards comparable
4. Training level of users involved in test
5. Ground-truth scenario system is evaluated against
6. Effect of stress (post trauma) & op environment on individual & group performance
7. Advantages/disadvantages of using drugs to enhance performance
8. Ability of machines to cater for human performance degradation
9. Must an outside team evaluate the team or can't be self evaluated
10. How are standards developed? Cultural differences
11. Quantifiable MOPs, MOEs
12. Use of subjective MOPs
13. Metrics - are they valid
14. Demonstrable differences
15. Built in system-human testing

Evaluating Performance: New ideas and possibilities

1. Count survivors (who won)
2. How close to maximum did people/system operate
3. Compare results with past situations
4. Computer records all operations (down to the mouse click) that user perform on system-measure most used, etc.
5. War game
6. Allies
7. Outside agencies to set standards and then evaluation of exercise
8. Propose model & trials to test model, refine as necessary; careful statistical analysis
9. Use evaluation throughout the operational system
10. Evaluate different aspects of the system
11. Establish built in monitor (tests for unobtrusive testing)

Evaluating Performance: Benefits

1. Set up evaluation ongoing teams/facilities

2. Identify deficiencies in H/W, S/W, training
3. Identify possible enhancements to H/W, S/W, i.e. Requirements definition
4. Feed into doctrine & tactics
5. Ensuring CF is greater 'bang for the buck'
6. Ensuring combat efficiency
7. Know where to redirect scarce resources
8. There is no basis for judging
9. Whether tech solutions are beneficial without this
10. Risk that users will be at the 'whim' of the next wave of technologies
11. Establish a measurement that will demonstrate improvement
12. Direct remedial training/equip changes

Evaluating Performance: Problems

1. Ground-truth is never known in real-world - how do you measure performance?
2. How do you identify the cause of problems? Human or machine
3. Must avoid human vs. machine perception
4. Humans don't like being evaluated & found wanting
5. No one likes being assessed and often do not react the same way for real scenarios as when they are being tested in simulation exercises
6. Difficult to define valid, reliable measures
7. Lack of testing vehicles - with controlled presentations
8. C2 systems too slow to change
9. Lag behind demand
10. Always first thing to drop off the list
11. Resources applied here take away from resources applied where it counts

Evaluating Performance: Gut Feeling

1. Too difficult
2. Not best use of resources
3. Too difficult
4. Critical - no matter how difficult
5. Absolutely essential
6. Vital - build it in
7. Essential for systems, may not be cost effective for people
8. Unsure of relative benefit

CONCEPT F: TRAINING

9. Can system be customised?
12. Wargaming real-time

22. Collecting information from structured exercises
24. Realistic training on the C2IS to practice C2 process using scenario simulation
28. Making the system sailor-proof
40. Total system integration
50. Effects of stress (all sorts)
51. Motivation
58. How a person understands what the limit of a system are?

Training: Information needs

1. The need to know the systems to train on
2. Standard operating procedures
3. Real world environment data, maps, DTED, orbat equipment
4. Potential opposing force doctrine/tactics
5. How much is required
6. Most effective means of training (cost effective?)
7. Different levels i.e. Chain of command vs. equivalent level
8. What kind of quality for simulation are the real thing or systems which are almost like what will be used
9. Use of GIS visual S/W, etc.
10. Use of objective vs. subjective measures of performance in training - relative validity
11. Can Comdr. be taught to think in new ways
12. Interpreting op systems/simulations in training
13. Failure node
14. Evaluation of training

Training: New ideas and possibilities

1. Embedded computer-based training where user can work alone with the computer & instructor
2. Distributed interactive simulation where multiple users can "play" against / with each other over the net.
3. AI based opposing force to act against C2IS systems/user in war game
4. Test vs. training exercises
5. Develop joint training scenarios using existing battle labs
6. Network into allied simulations for combined training
7. Use feedback on performance to trainers
8. Use systems/prototype for training
9. Simulations
10. 'Real-life' war games
11. Virtual reality

12. Sleep training
13. Drug enhanced training
14. Distance learning

Training: Benefits

1. Will allow full exploitation of system potential
2. Scenarios might be used for 'plans' development
3. Detailed simulation would lessen the requirement for 'real' ops exercises (or more could be extracted from 'real' ops)
4. Decreased costs (same bang for smaller dollar)
5. More complex unit training
6. Small investment large pay off (the people are what makes the system work)
7. Greater buy in for new systems
8. Can use to modify training requirements
9. Make best use of systems at hand
10. Better prepare us for the real thing
11. Better user acceptance of C2IS system
12. Better user feedback on system capabilities/deficiencies

Training: Problems

1. Simulation is never like the real thing (has to feel sea sick in a trainer)
2. Errors in simulation can be easily pushed aside, not so in the real world
3. No serious (possibly fatal) penalty if you screw up (A/C doesn't crash, ship doesn't hit dock, you don't get shot) .
4. Hard to organize
5. Training difficult to change (institutional inertia)
6. Expensive
7. Personnel turnover
8. Higher and higher qualification for trainee
9. How do we know what to train when things change so quickly
10. Trained people leave for other pastures outside DND
11. Who makes up training exercises for C2IS systems?
12. How do you train one combat function independently from all others?
13. Looks expensive to replicate system - generic ones not well accepted by operators

Training: Gut Feeling

1. Fundamental
2. Key to successful engagement/soldiering

3. Obvious
4. What's new?
5. Nothing new
6. Key part of puzzle
7. C2IS is useless without proper training must have combat, war games etc.
8. All of the above

CONCEPT G: KNOWLEDGE ENGINEERING

9. Can system be customised?
15. Collecting information for real world operations
17. Heuristics
18. Explanation based systems
19. Environmental knowledge, forecasting and control
20. Information mining
22. Collecting information from structured exercises
24. Realistic training on the C2IS to practice C2 process using scenario simulation
27. Confirming requirements through evaluation with real users
28. Making the system sailor-proof
32. How does C2IS support Force effectiveness. How can it be measured?
33. Ability to exploit our small community to work together better
35. Reducing uncertainty through expert systems
37. Domain knowledge engineering
38. Neural networks for decision making
43. Confidence in information
44. Reliability of information
45. Fuzzy logic
47. Fragility of information units
57. Personality factors that influence decision-making
58. How a person understands what the limit of a system are?

Knowledge engineering: Information needs

1. Access to domain experts/users
2. Standard operating procedures
3. Objective of C2 process
4. Data dictionary of terms
5. Sensor data
6. Heuristics (how decisions are reached)
7. Artificial intelligence
8. Fuzzy logic
9. Effect of gradual degradation of info input

10. Data bases for sensors/operators & automatic systems
11. Current limitations of ANNs, AI, ESs, KBSs, blackboard systems
12. Allied research US, UK, As, NATO, - mil/academic
13. Validating knowledge structures methods
14. How commanders think, can old dogs be taught new tricks
15. How to train new commanders
16. Cybernetics & knowledge work
17. Interoperability
18. Methods of data exchange

Knowledge engineering: New ideas and possibilities

1. Knowledge/heuristics, rules of thumb
2. Exchange data with allies, exchange data with industry/academic
3. Develop/propose standards
4. Test fuzzy logic in component systems & work up
5. Use existing S/W (COTS/GOTS)
6. KE lab with taping/sensor capture to mine expert opinion
7. Explore Delphi techniques for KE effect of several provides
8. Use operators for development
9. Cross train developers in ops
10. Advanced training for staffs
11. No R&D; let commercial sector do it
12. Use machine learning (inactive) techniques to study actions & decisions of users-use this to make rule based systems.

Knowledge engineering: Benefits

1. Reduce manpower requirements
2. System would require smaller area (spec allocation)
3. Less training required because of experts in a box
4. Can lead to further efficiencies
5. This is one basis for decision support technologies decision support is the prime function of tech
6. Better understand decisions/judgement & support it.
7. Important info given priority processing
8. More accurate decisions
9. Lets human so what they do better and lets machines do what they do better i.e. Better use of resources
10. Reduce human error
11. Maintain and share knowledge of specific domain experts with all users.
12. Consistency & predictability i.e. Decisions
13. Develop SOPs is slow considered by experts

Knowledge engineering: Problems

1. KE includes AI, ANN, ESs, KBSs 'blackboard' system don't deliver what they promise
2. The cost, to payoff
3. System will eventually fail with probability 1.0
4. Resulting systems are strongly based by population, sampled, and by technique
5. Huge effort and data set required before any such knowledge system is usable
6. Danger of too much reliance on validity of knowledge - based systems
7. Not fruitful to date
8. Don't have true experts in house (perception)
9. Too expensive
10. Too much bandwidth
11. Computers break down i.e. Reliability
12. This stuff is not understandable by users so there is a lack of trust
13. This new edge of technology is unproved, likely to be some big wastes of time/effort
14. This is a big leap - change is hard
15. How do you capture user's knowledge and behaviour in performing tasks?
16. May be too predictable
17. AI is only as good as the I, difficult to change it quickly if the tech changes

Knowledge engineering: Gut Feeling

1. Balls!
2. Over ambitious
3. Not yet
4. Over played
5. Over my head maybe important future
6. Simple systems are better than complex ones
7. User understanding & trust is essential
8. Follow US lead
9. What the first person said!

CONCEPT H: TEAMWORK

9. Can system be customised?
13. Redefining staff roles
14. Team dynamics and decision making
28. Making the system sailor-proof

30. Parallel planning. Real-time co-authorship
33. Ability to exploit our small community to work together better
34. Security and sharing information
36. Distributed decision making
40. Total system integration
42. Non-verbal communication. How important is it in decision-making and teamwork?
48. Span of control
51. Motivation
56. Ability of commander directly impact
57. Personality factors that influence decision-making

Teamwork: Information needs

1. Team dynamics i.e. How people interact
2. Leadership
3. Non verbal communications
4. Effect of stress
5. How to motivate in 21st century
6. Who makes up the team, at what level (tactical, operational, strategic)
7. Training
8. What are the effect of different personalities on team performance
9. Theory of teamwork
10. What should be the role of the team leader
11. Team builders as system architects
12. New staff models - what are they
13. How to maintain contact with team
14. How to assess individuals in team
15. Role of functional leaders
16. Affect of task leadership and team maintenance leadership
17. How does H/W, S/W play a part of a team

Teamwork: New ideas and possibilities

1. Command team training facilities
2. Joint exercises
3. Video tape team training - play back in slo'mo' or real time
4. Freeze frame
5. Add graphics (football type)
6. Explore use of non-conventional settings for establishing teams
7. Explore use of stress for slowing team breakdown
8. Use operators maximum extent possible detailed controlled/unstructured tests

9. Use system to train/validate
10. Rapid reward system
11. Keep people in teams for long periods (a year or longer) to develop team habits
12. Have teams compete against each other for best score during simulated and real-world exercises
13. Determine characteristics, develop culture, recruit team players

Teamwork: Benefits

1. Increased effectiveness at same cost/resource or same effectiveness at lower cost/resources or ideally more with less
2. Emphasis in research and training for teamwork is a small investment compared to other technologies, and may offer very large benefits.
3. Great improvements in decision time, orders/instructions in writing
4. Synergism of team vs. individuals
5. Better use of diminishing resources
6. Good teamwork can be a force multiplier
7. Teach users how to use C2IS as part of the team
8. Training of team
9. Retention of trained personnel & cost avoidance retraining
10. Motivates the team to succeed

Teamwork: Problems

1. Complex issue
2. Hard to get sufficient subjects for studies
3. Field studies confounded with other factors
4. Hard to develop working model
5. Butts against doctrinal transience
6. Resistance by users/operators
7. Always a weak link
8. People are unreliable
9. Decisions in teams can be slow and of poor quality
10. Teams don't work well with all groupings of people
11. How does machine fit into team?
12. How does training impact? What is required?
13. Postings etc. Facts of life make team maintenance a real problem
14. Decision by committee (consent too time consuming & must not be encouraged
15. In the end the commander is responsible for the decision not the team
16. Somebody will always take an opposing view (me-me-me attitude)

Teamwork: Gut Feeling

1. Critical
2. Hard motherhood
3. Motherhood
4. Training
5. Needed for info access to KE etc.
6. Criticism
7. Motherhood maybe, but is damn important!

PRIORITIZATION

VOTING SUMMARY[1]

	P1	P2	P3	P4	P5	P6	P7	P8
A. Presentation of Info	1	2	7	1	1	1	5	1
B. Information Access	2	5	6	3	3	4	4	3
C. Decision Support	3	1	1	2	2	2	1	2
D. Human Performance	4	4	5	5	8	3	8	4
E. Evaluating Performance	8	3	2	6	6	6	6	5
F. Training	5	6	3	7	4	8	2	6
G. Knowledge Engineering	7	8	8	4	7	5	3	8
H. Teamwork	6	7	4	8	5	7	7	7

AVERAGE RANK

	Ave Rank
A. Presentation of Info	2.4
B. Information Access	3.8
C. Decision Support	1.8
D. Human Performance	5.1
E. Evaluating Performance	5.3
F. Training	5.1
G. Knowledge Engineering	6.3
H. Teamwork	6.4

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[1] Table format: columns show prioritized concepts (1..8) from each player (P1..P8); rows show votes for each concept (A..H).

ANNEX B
ORD PROJECT REPORT PR 9620
DECEMBER 1996

SYNDICATE 1B: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN HUMAN FACTORS FOR COMMAND AND CONTROL

INTRODUCTION

B-1. Syndicate 1B was asked the same question as syndicate 1A:

"What human factors R&D is required and what opportunities does it provide, to support the CF in its Command and Control functions?"

This syndicate went through the process of Idea Generation and Concept Grouping, then Concept Development and Prioritisation. The syndicate developed 37 ideas which were grouped into the following six concepts:

a. Training;

b. User interface;

c. Decision support;

d. Teamwork;

e. Leadership; and

f. Performance Measurement.

B-2. The following format is used in documentation. For each concept:

a. Idea base for each concept (generated via Nominal Group Technique);

b. Idea development for each concept (generated via Six Thinking Hats):

(1) Information needs;

(2) Creative solutions;

(3) Benefits;

(4) Problems; and

(5) Gut feelings;

c. Prioritization (anonymous syndicate member votes).

B-3. Voting results did not appear to indicate group consensus. The data was also analyzed using a computer-based consensus analysis program. A statistically significant degree of consensus was *not* found in the votes recorded for this syndicate group. Voting results and average ranks appear at the end of this annex.

IDEA INVENTORY

1. Team dynamics - trust and confidence.
2. Effectiveness of input devices.
3. Fuse information so that it doesn't have to be mentally manipulated.
4. Threshold of information overload.
5. Front-end analysis of job functions.
6. How do you get a user to coherently express criticism.
7. Realistic simulation and training capability.
8. Decision making under stress.
9. To what extent do automated systems limit flexibility and freedom of decision making.
10. Implications of Real Time versus Non-Real Time decisions and information.
11. How busy should a PC screen be.
12. Measures of performance integrating human and systems parts.
13. Interoperability across environments.
14. Productivity in information handling under severe fatigue conditions.
15. Adaptable software with staff of unequal abilities.

16. Man-machine interface.
17. Colour, sound, motion as output device enablers.
18. What are the best colour contrast for representation of information.
19. What do colours represent (attracts attention).
20. Analogue versus digital representation of data.
21. Team decision making techniques.
22. Optimal flow of information in distributed system environment.
23. Training issues in complex systems.
24. How do you make people understand the feasibility of new systems.
25. System inputs should minimize human interface requirements.
26. Depersonalization of systems.
27. How to prioritize E-mail - urgency versus importance.
28. Team training versus individual training.
29. How to exploit the full capability of teams.
30. Information sharing techniques for teams to come up with better decisions.
31. How to get nuance on E-mail.
32. How does one propagate leadership in an automated world.
33. Opportunities for micro-management due to technology.
34. How to continue functions when disconnected to E-mail.
35. Decision support - when should they be used (what should be automated).
36. What are we training for - functions of the job - marry human capabilities to job function.
37. Training reinforcement.

CONCEPT A: TRAINING

3. Fuse information so that it doesn't have to be mentally manipulated.
4. Threshold of information overload.
5. Front-end analysis of job functions.
6. How do you get a user to coherently express criticism.
7. Realistic simulation and training capability.
8. Decision making under stress.
9. To what extent do automated systems limit flexibility and freedom of decision making.
10. Implications of Real Time versus Non-Real Time decisions and information.
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15. Adaptable software with staff of unequal abilities.
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35. Decision support - when should they be used (what should be automated).
36. What are we training for - functions of the job - marry human capabilities to job function.
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Training: Information Needs

1. Rank level or performance level
2. Fidelity requirement
3. Operational requirements
4. Realistic simulation
5. Currency of information
6. System credibility
7. Ease of use
8. Mission
9. Measurement
10. Troop fidelity requirements (real equip or simulator)
11. Frequency/refresher

Training: Creative solutions

1. Integration into operational system
2. Train as you'd fight (simulation)
3. Deployable systems same as those in garrison
4. Train only to level required
5. Rapid reinforcement capability

6. Command laboratory
7. Integrate training with doctrine & lessons learned
8. Stimulation capabilities

Training: Benefits

1. More efficient use of resources
2. More capable personnel
3. Better decision making
4. Error avoidance (minimization of errors)
5. Longer retention - less need for retraining

Training: Problems

1. Overtraining
2. Tokenism (ticket punching)
3. Under training
4. Improper training (not pertinent to job/task)
5. Fatigue
6. Mistrust
7. Training doesn't generalize to operational environment
8. Cost/afford ability

Training: Gut feeling

1. Much already done in industry - might not be a valid use of R&D funds
2. Absolutely necessary
3. Not required as R&D
4. Unsure
5. Is required as part of leadership & teamwork R&D
6. Can cut costs if personnel have a wide range of skills

CONCEPT B: USER INTERFACE

1. Team dynamics - trust and confidence.
2. Effectiveness of input devices.
3. Fuse information so that it doesn't have to be mentally manipulated.
4. Threshold of information overload.
5. Front-end analysis of job functions.
6. How do you get a user to coherently express criticism.
7. Realistic simulation and training capability.
8. Decision making under stress.
9. To what extent do automated systems limit flexibility and freedom of

decision making.

10. Implications of Real Time versus Non-Real Time decisions and information.
11. How busy should a PC screen be.
12. Measures of performance integrating human and systems parts.
13. Interoperability across environments.
14. Productivity in information handling under severe fatigue conditions.
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33. Opportunities for micro-management due to technology.
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35. Decision support - when should they be used (what should be automated).
36. What are we training for - functions of the job - marry human capabilities to job function.
37. Training reinforcement.

User Interface: Information Needs

1. System requirements
2. Environment in which it will be used
3. Amount and type of info to be presented
4. Speed of response required
5. Timeliness of response
6. Type of input and output (e.g. sound, keyboard, video, etc.)
7. Output fidelity
8. Accuracy of output
9. Conscience/brevity of input

10. Equipment location
11. Operator capabilities
12. Training requirements

User Interface: Creative solutions

1. Ask people what they need
2. Trial & error
3. Virtual prototyping
4. Research user limitations and capabilities
5. Provide systems with multiple input devices
6. System appropriate to the environment
7. User-friendly presentation/applications
8. Comfortable working environment
9. Command laboratory

User Interface: Benefits

1. System utilization increase
2. Less user fatigue/stress
3. User performance increase
4. Decision effectiveness (timeliness/accuracy/speed)
5. Separate the urgent & important from the routine
6. Less fatigue
7. Common tools

User Interface: Problems

1. System non-use
2. User fatigue/stress
3. Inaccuracy of input and output
4. Requirements for larger resource base
5. Loss of team cohesiveness
6. Can be more expensive
7. May look pretty, but is it functional

User Interface: Gut feeling

1. Yes - system utilization/performance increases necessary with today's downsizing
2. Needed, very much so
3. Necessary
4. Critical area for R&D

5. Is not an especially critical area for R&D but applications of principles is important.
6. Is usually considered more important than it really is
7. Good MMI is the result of previous human factors research in other areas.

CONCEPT C: DECISION SUPPORT

1. Team dynamics - trust and confidence.
2. Effectiveness of input devices.
3. Fuse information so that it doesn't have to be mentally manipulated.
4. Threshold of information overload.
5. Front-end analysis of job functions.
6. How do you get a user to coherently express criticism.
7. Realistic simulation and training capability.
8. Decision making under stress.
9. To what extent do automated systems limit flexibility and freedom of decision making.
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32. How does one propagate leadership in an automated world.
33. Opportunities for micro-management due to technology.
34. How to continue functions when disconnected to E-mail.

35. Decision support - when should they be used (what should be automated).
36. What are we training for - functions of the job - marry human capabilities to job function.
37. Training reinforcement.

Decision Support: Information Needs

1. Mission
2. Intelligence
3. Confidence of tools
4. Confidence of personnel
5. Training
6. Experience
7. Situation
8. Level of uncertainty of info
9. Complexity of environment
10. Timeliness
11. Rules of engagement
12. Theatre of operations
13. Logistics (availability of support)
14. Timeliness

Decision Support: Creative solutions

1. Requirements for decision support tools
2. Accuracy of information
3. Timeliness of information (near real-time)
4. Leadership/management training
5. Clear statement of objectives/aim
6. Development of "gaming" simulators
7. Command laboratory
8. Teach alternative decision making techniques e.g. lateral thinking

Decision Support: Benefits

1. Reduction of info overload
2. Reduction of manning
3. Reduction of equipment
4. Reduction of unit size
5. Maximum benefit of resources
6. More rapid decisions
7. More accurate decisions
8. Cohesiveness & trust within the team

9. Increase tempo of operations
10. Free up manpower for other more critical tasks

Decision Support: Problems

1. Auto system downplaying role of humans
2. Dependence on automated system (lack of creativity)
3. Inaccurate decisions
4. Mistrust of leadership
5. Auto systems rigidify organization

Decision Support: Gut feeling

1. Very difficult area but absolutely essential
2. Don't believe that decision making can be fully automated
3. Excellent idea, needed but could be a sink hole of funds needs analysis
4. Necessary for effective use of the system, good R&D subject
5. Helpful
6. Very good idea
7. Role of decision maker & processor in organization

CONCEPT D: TEAMWORK

1. Team dynamics - trust and confidence.
2. Effectiveness of input devices.
3. Fuse information so that it doesn't have to be mentally manipulated.
4. Threshold of information overload.
5. Front-end analysis of job functions.
6. How do you get a user to coherently express criticism.
7. Realistic simulation and training capability.
8. Decision making under stress.
9. To what extent do automated systems limit flexibility and freedom of decision making.
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35. Decision support - when should they be used (what should be automated).
36. What are we training for - functions of the job - marry human capabilities to job function.
37. Training reinforcement.

Teamwork: Information Needs

1. Knowledge of team skills - communication, training, experience, leadership
2. Mission
3. Resources
4. Cohesiveness of the group
5. Trust (in the system & the individuals of the group)
6. Reliability (personnel and system)
7. Aids developing dynamism
8. Team structure-rank or skill or experience
9. Team size required

Teamwork: Creative solutions

1. Gaming & information sharing
2. Shared mental models
3. Synchronization among team members (scheduling)
4. Clear aim/objective conveyance
5. Distribution of information
6. Capability of equitable work sharing (automated)
7. Command laboratory

Teamwork: Benefits

1. Efficiency of operations
2. Improved synchronization
3. Improved morale
4. Group cohesiveness
5. Greater motivation
6. Cross training
7. Morale

Teamwork: Problems

1. Lack of leadership (waiting for group decisions)
2. Break up of team
3. Inaccurate decisions
4. Lack of communication
5. Loss/abandonment of mission/aim
6. Group think (cliques)
7. Weakening of chain of command

Teamwork: Gut feeling

1. An important R&D area, that will result in improved training, leading to optimal operational performance.
2. Yes, must be established how best to function as a team to achieve the best results.
3. Agree, good R&D subject normally overlooked in most projects
4. With reduced manning and wider scope of operations teamwork is going to become a critical issue
5. Good teamwork can make up for a lot of bad design in C2 systems.
6. Good idea and tough to do - a possible sink hole of funds

CONCEPT E: LEADERSHIP

1. Team dynamics - trust and confidence.
2. Effectiveness of input devices.
3. Fuse information so that it doesn't have to be mentally manipulated.
4. Threshold of information overload.
5. Front-end analysis of job functions.
6. How do you get a user to coherently express criticism.
7. Realistic simulation and training capability.
8. Decision making under stress.

9. To what extent do automated systems limit flexibility and freedom of decision making.
10. Implications of Real Time versus Non-Real Time decisions and information.
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36. What are we training for - functions of the job - marry human capabilities to job function.
37. Training reinforcement.

Leadership: Information Needs

1. Job knowledge
2. Skills
3. Training
4. Experience
5. Performance
6. Potential
7. Loyalty
8. Respect

9. Motivation
10. Creativity
11. Charisma
12. Language skills
13. Trust of subordinates
14. Tact
15. Personality
16. Communications ability

Leadership: Creative solutions

1. Rotate leader regardless of rank - shared mental models
2. Have more realistic exercises
3. Integrate lessons learned with training
4. Gaming simulators
5. Selection techniques
6. Leadership/management training capability
7. Benchmarks/gauges
8. Command laboratory

Leadership: Benefits

1. Improved decisions
2. Accuracy of decisions
3. Trust of leadership
4. Timeliness of decisions
5. Improved team morale
6. Greater motivation
7. Greater initiative

Leadership: Problems

1. Ergonomics
2. Dictatorship
3. Anarchy (lack of leadership)
4. Coup d'état
5. Narrow mindedness
6. Micro-management
7. Loss of trust
8. Break-up of group
9. Mutiny
10. Fear of selection in inappropriate leaders

Leadership: Gut feeling

1. Yes to establish what is required & how it should be done.
2. Leadership & teamwork are necessary arrangements of C2 systems
3. Helpful
4. Not a valid use for our scarce R&D funds
5. Not necessary as an R&D subject, can be evaluated through other methods
6. Absolutely critical for C2 systems to work well
7. An essential component of Command
8. Without good leadership (and what that entails) C2 systems can fail

CONCEPT F: PERFORMANCE MEASUREMENT

1. Team dynamics - trust and confidence.
2. Effectiveness of input devices.
3. Fuse information so that it doesn't have to be mentally manipulated.
4. Threshold of information overload.
5. Front-end analysis of job functions.
6. How do you get a user to coherently express criticism.
7. Realistic simulation and training capability.
8. Decision making under stress.
9. To what extent do automated systems limit flexibility and freedom of decision making.
10. Implications of Real Time versus Non-Real Time decisions and information.
11. How busy should a PC screen be.
12. Measures of performance integrating human and systems parts.
13. Interoperability across environments.
14. Productivity in information handling under severe fatigue conditions.
15. Adaptable software with staff of unequal abilities.
16. Man machine interface.
17. Colour, sound, motion as output device enablers.
18. What are the best colour contrast for representation of information.
19. What do colours represent (attracts attention).
20. Analogue versus digital representation of data.
21. Team decision making techniques.
22. Optimal flow of information in distributed system environment.
23. Training issues in complex systems.
24. How do you make people understand the feasibility of new systems.
25. System inputs should minimize human interface requirements.
26. Depersonalization of systems.
27. How to prioritize E-mail - urgency versus importance.
28. Team training versus individual training.

29. How to exploit the full capability of teams.
30. Information sharing techniques for teams to come up with better decisions.
31. How to get nuance on E-mail.
32. How does one propagate leadership in an automated world.
33. Opportunities for micro-management due to technology.
34. How to continue functions when disconnected to E-mail.
35. Decision support - when should they be used (what should be automated).
36. What are we training for - functions of the job - marry human capabilities to job function.
37. Training reinforcement.

Performance Measurement: Information Needs

1. Outcome vs. Process, criteria, speed vs. accuracy, stress level anticipated, quantitative vs. qualitative.
2. Measures of effectiveness versus measures of performance
3. Integrate PM into WPM system of platform
4. Training effectiveness
5. Personnel adaptive flex
6. Capability of personnel
7. Working environment

Performance Measurement: Creative solutions

1. Benchmarks
2. Training standards
3. Environmental conditions (workplace location)
4. Adaptive displays (HCI)
5. Establish of performance criterion guidelines based on individual capabilities
6. Command laboratory
7. Embed performance measurement tools in actual systems

Performance Measurement: Benefits

1. Performance history over long periods (trends)
2. Aid in planning and doctrine
3. Fine tuning training (or when not to overtrain)
4. Establishes best use of resources
5. Establish standards
6. Identifies potential of personnel
7. Minimizes future errors
8. Increases efficiency and accuracy of operations

Performance Measurement: Problems

1. Improper measurement leads to future errors
2. Demoralization of personnel
3. System non-use due to fear/trepidation of standards
4. Big brother atmosphere
5. Emphasis on quantity rather than quality
6. Large (very large) data bases
7. Requires interpretation
8. Over/under estimate PM.
9. PM may be too intrusive
10. "system effective"

Performance Measurement: Gut feeling

1. Agree, opportunity for high payback
2. If performance measurements are embedded in operational systems, then it can be successful
3. Must be implemented as part of the overall culture - so that it is more easily accepted.
4. May not be necessary as an R&D subject
5. Helpful
6. An essential component for improving performance, but must not be intrusive.

PRIORITIZATION

VOTING SUMMARY

	P1	P2	P3	P4	P5
A. Training	2	3	5	4	3
B. User interface	1	2	6	3	4
C. Decision support	3	5	2	1	3
D. Teamwork	4	6	3	6	1
E. Leadership	5	7	4	5	2
F. Performance Measurement	7	4	1	2	3
G. Knowledge Elicitation	6	1	7	7	5

AVERAGE RANK

	Average Rank
A. Training	3.4
B. User interface	3.2
C. Decision support	2.8
D. Teamwork	4.0
E. Leadership	4.6
F. Performance Measurement	3.4
G. Knowledge Elicitation	5.1

SYNDICATE 1C: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN ANALYTICAL METHODS FOR COMMAND AND CONTROL

INTRODUCTION

C-1. Syndicate 1C was asked the following question:

> **"What operational research and systems analysis are required and what opportunities do they provide, to support the CF during the complete life-cycle of C2IS?"**

This syndicate went through the process of Idea Generation and Concept Grouping, then Concept Development and Prioritisation. The syndicate developed 36 ideas which were grouped into the following seven concepts:

a. Life cycle process modification;

b. Performance modelling/ development lab;

c. Feedback;

d. Requirements capture;

e. Operational research;

f. Data/ information/ knowledge capture; and

g. Fielding.

C-2. The following format is used in documentation. For each concept:

a. Idea base for each concept (generated via Nominal Group Technique);

b. Idea development for each concept (generated via Six Thinking Hats):

(1) Information needs;

(2) Creative solutions;

(3) Benefits;

(4) Problems; and

(5) Gut feelings;

c. Prioritization (anonymous syndicate member votes).

C-3. Voting results were tabulated. Results and average ranks appear at the end of this annex. This syndicate assessed concepts in the following approximate order of priority:

a. Requirements capture (Concept D);

b. Fielding (Concept G);

c. Performance modelling/Development lab (Concept B);

d. Feedback (Concept C);

e. Life cycle process modification/Systems engineering (Concept A);

f. Data/information/knowledge capture (Concept F);

g. Operational Research (Concept E).

IDEA INVENTORY

1. Separate C2IS into manageable components.
2. User as a developer in the C2 process.
3. Evaluate failure and shortfalls of first generation C2IS.
4. A place where the user can go and help define requirements.
5. Constant assessment of system vulnerabilities.
6. Commitment by the user.
7. Simulation.
8. Traditional requirements analysis does not pertain to IT.
9. How do we adapt/adopt COTS/GOTS/MOTS and other OTS systems to our unique CF requirements?
10. C2IS exposure and understanding CF-wide.
11. Capability of developers to experience real life.
12. Information support to handle information fusion/ correlation/ fitting.
13. Requirements capture and methodology.
14. Ways to predict impact on other operations.
15. Re-engineer the R&D process (R&D integrated into service delivery - regroup work).
16. Measure effectiveness of C2 system.
17. Primacy of time limited vs. complete solutions.
18. Collect what allies are doing and see what their successes and failures are.
19. Interoperability - what changes can be built into the system to accommodate the future?
20. Automated decision making (e.g., Co-operative Engagement Capability) - how far do you go?
21. Systems that can evolve as new capabilities emerge.
22. What is the best cycle for R&D?
23. Get the best 80% in the 80/20 solution.
24. What is technically possible now and in the future?
25. What is technically supportable now and in the future?
26. Technical abilities to do something does not make it a requirement.
27. Technology mission creep.
28. What is software development cycle for maintainability?
29. Re-use of software / libraries.
30. Life cycle management - paradigm of 'endless cycle'.
31. OR critical in payback analysis.
32. Studying concepts of information ageing.
33. Conversion of information into knowledge.
34. How much information is there really?
35. Who needs what/ when? (information requirements)
36. Data compression/ reformatting/ filtering.

CONCEPT A: LIFE CYCLE PROCESS MODIFICATION

1. Separate C2IS into manageable components.
2. User as a developer in the C2 process.
6. Commitment by the user.
7. Simulation.
17. Primacy of time limited vs. complete solutions.
21. Systems that can evolve as new capabilities emerge.
22. What is the best cycle for R&D?
28. What is software development cycle for maintainability?
29. Re-use of software / libraries.
30. Life cycle management - paradigm of 'endless cycle'.
31. OR critical in payback analysis.
35. Who needs what/ when? (information requirements)

Life Cycle Modification: Information needs

1. Need to be able to define modified process in relationship to current life cycle process and how it is different for Info systems
2. Need to capture foreign experiences with C2IS - eg. French have learned that the ideal development cycle for IS is two years with three versions being developed at one time.
3. Need to identify users (experienced)
4. Need to determine when a solution is good enough vs. the optimum solution
5. Need to understand how to reuse software - How to build & use software
6. Identification of information - input - data base - output
7. Identification of algorithms for filtering, fusion, etc.
8. Identification of core software, baseline infrastructure
9. How do new fiscal realities affect system engineering?
10. How to accommodate rapid development with DPMS
11. What are training requirements for info handling (input, filtering etc.)
12. Successes/failures of past systems and S.E. analysis of what went right or wrong

Life Cycle Modification: Creative solutions

1. When a new solution emerges from lab, obtain commitment/endorsement from users (if solution is eventually fieldable)
2. Offer incentive (increased pay, free time off, new car etc.) depending on amount of quantifiable savings/improvements
3. Lock in a project manager for a set time period until project completion and project redevelopment has undergone at least 1 cycle.

4. Change DPMS & TB procedures to allow for evolutionary development
5. Recognize that IS projects don't have a definable conclusion and allow for allocation of "project" money over the life of the C2IS vs. relying on O&M funds after fielding
6. Have R&D personnel involved in total life of project, not just R&D phase
7. Minimize hand-offs during project for improved continuity
8. Define the system in terms of its functional flow and then upgrade hardware/software capabilities as newer equipment becomes available
9. Consider new methods of upgrading systems - e.g. Keep a constantly changing development lab and periodically define standards based on this lab for field upgrades
10. Rotate users through engineering staff/scientific staff and scientific/engineering staff in operational job
11. Increase availability of operational training for scientific/OR staff, also engineering staff
12. Creation of short-lived tiger teams for quick hits on problems
13. Do some research on system engineering technology (through industry or university)
14. Adopt rapid prototyping techniques vs. sequential "waterfall" system development

Life Cycle Modification: Benefits

1. Reduced costs because less large, risky projects
2. Continuously improving capability instead of infrequent quantum jumps
3. Capability fielded sooner as development cycle is reduced
4. Must buy-in at all levels - better quality systems
5. More easily maintained so more easily modified to meet user needs
6. Use of system review process will ensure that system is meeting user needs thus reducing user acceptance risk
7. Increased confidence by user and developer resulting in acceptance
8. Flexible system engineering based on user involvement & rapid prototyping will ensure that systems can meet the users needs and can be fielded rapidly.
9. Allows for fielding to be done within the cycle of technology change (18-24 months)
10. Allows new functionalities to be implemented as they are developed and/or as new requirements arise
11. Allows for easy retrofitting (technology insertion)
12. Results in more complete solutions minimizing constant re-evaluation
13. Easier transition from concept (lab) to field (maintenance etc.)

Life Cycle Modification: Problems

1. Requires major changes to how DND & TB approves C2IS projects
2. Constant training needed
3. Better trained soldiers may be difficult to retain
4. Technology training versus trade training
5. Configuration management difficult
6. Fielding now of partial solution may make it difficult to get further improvement
7. Constant upgrading = lots of down time for retrofit
8. System sort of works now, change may make it worse
9. Will result in more money & resources used
10. Confusion with changing procedures
11. Project managers are unlikely to change their generally cautious approach towards technological change, documentation, etc. Too much investment in "old" system engineering process both in terms of personnel & money therefore difficult to change
12. Software reuse/sharing will impact on intellectual property rights depending on how software was developed.
13. Users/operators are sick & tired of engineering - "I just want a solution now!"
14. Rapid deployment of systems which have not had sufficient time for engineering development could temporarily cripple a fighting force & increase tremendous costs
15. More time required up front, changes distribution of resources - reorganization required

Life Cycle Modification: Gut feeling

1. Yes
2. No, CF is tired of "re-this" "re-that" - CRAD as well!
3. Undecided
4. Yes, but will take too long to implement
5. Any advice is possible?
6. Form "battle lab" system engineering is almost always slightly behind the times because it is developed around past successes and failures; however, an evolving system engineering process is likely still the best way to develop & administer large projects
7. Lab personnel are not trained in system engineering
8. We choose our scientists for their expertise and we evaluate them (Personnel Evaluation Report) accordingly: system engineering will need to be developed among our scientific staff

9. Not enough people to collocate teams almost nobody can be dedicated to one project anymore
10. No, the attitude of "look how far we've come" causes people to believe the system is not flawed significantly

CONCEPT B: PERFORMANCE MODELLING/ DEVELOPMENT LAB

4. A place where the user can go and help define requirements.
7. Simulation.
23. Get the best 80% in the 80/20 solution.
24. What is technically possible now and in the future?
25. What is technically supportable now and in the future?
26. Technical abilities to do something does not make it a requirement.

Performance Modelling: Information needs

1. Simple versus complex technologies
2. Agreed architecture
3. Location contributed..
4. Roles prioritized
5. Ownership/control R&D/user/engineers
6. Cost sharing
7. Help from creative elements of society (film & TV, advertising, arts)
8. How have allies dealt with this problem?
9. Structure - distributed versus single location
10. What system(s) do we want to model
11. Is there a standard simulation software? Is there need to be more than 1 standard.
12. What is current state-of-art
13. What is possible in future
14. To what extent is the modelling likely to reflect the actual performance of the system?

Performance Modelling: Creative solutions

1. Distributed lab concept with clear relationships between users & developers
2. Put lab with users therefore mobile capability
3. Integrate simulation capability with lab
4. Multiple levels of simulation with wide distribution of "gross level" for quick and dirty
5. Make battle lab integrate with live systems to improve exercises

Performance Modelling: Benefits

1. Cost savings are high in relation to actually using model to perform task
2. Realize problems before they become insurmountable
3. Requirements better focused
4. Better methodology for MOP
5. Assures continuity on requirements over user's posting cycle
6. Focal point for system review, studies
7. More stable fielded system

Performance Modelling: Problems

1. Distributed lab puts heavy load on communication
2. Development lab could utterly fail to predict real performance of system
3. Lab is unlikely to encounter operational conditions (i.e. in turbulence or wave action)
4. Current downsizing of CF has not identified money & people to form lab
5. Might not be an accurate representation of the operation
6. Uses resources (computer, personnel) that CF could use elsewhere
7. Fights for use/control of labs - conflicting priorities

Performance Modelling: Gut feeling

1. Should be essential, but doubt resources are available to make it work and maintain it.
2. Needed. May be possible using current resources
3. Yes, part of the way we do things in this period of history
4. Yes, but only if it is in Kingston
5. Yes, but decider will be personnel & facilities
6. Yes, but link (Internet-like technologies?) labs and users
7. Yes, is absolutely essential in order to test gradual improvements to system

CONCEPT C: FEEDBACK

2. User as a developer in the C2 process.
3. Evaluate failure and shortfalls of first generation C2IS.
5. Constant assessment of system vulnerabilities.
10. C2IS exposure and understanding CF-wide.
11. Capability of developers to experience real life.
16. Measure effectiveness of C2 system.
19. Interoperability - what changes can be built into the system to accommodate the future?

Feedback: Information needs

1. What info must be presented to users to make their job more easy/efficient
2. Impact of info on conduct of operations
3. Info push vs. pull (but info needs to be available for consultation/use)
4. Interaction users - developers (R&D)
5. Analyse lessons learned from previous or existing C2IS before fielding new version/system
6. Need formal feedback system to capture user feedback and input into system development
7. Feedback must be obtained from the user while on ops/ex (i.e. While he/she is operating in the target environment) as the feedback/experience is very perishable

Feedback: Creative solutions

1. 1-(800) number for specific projects
2. Make senior commanders use systems ASAP, then call a meeting
3. Build on a lessons-learned capability which formally captures post-op/post-ex reports & mandates updates to users
4. Implicate users by designating a unit/formation (BDE) as the test unit for C2 systems
5. Have regular conferences with users and developers
6. Bring users into test lab

Feedback: Benefits

1. Developers will experience real life
2. Better targeted R&D
3. Improved conveyance to a useful product
4. Allows for incorporation of changes which reflect - changing requirements, better processing, emergent technologies, more appropriate operation use of system
5. Serves to maintain steady liaison between users and developers - handy in system upgrades or development of follow-on systems.
6. User has a venue to express his problems, therefore happier user
7. User is involved in system development, therefore user will accept system more readily

Feedback: Problems

1. More feedback given - more resources needed to give and analyse feedback

2. Feedback means adaptation and reorientation from scientist: what about his area of expertise (or his pet project)?
3. Formal mechanism needed to ensure feedback between users and developers
4. Labs and/or users are dispersed
5. Too much feedback might result in desensitizing project developers
6. Developers side tracked by users, always changing design and never fielding operational system
7. User feedback may not be constructive and left to developers to accept/reject

Feedback: Gut feeling

1. Essential! R&D issue?
2. Critical to success of C2IS development
3. Yes
4. Yes, people like to point out what's wrong & usually give recommendations
5. Yes, absolutely essential

CONCEPT D: REQUIREMENTS CAPTURE

2. User as a developer in the C2 process.
3. Evaluate failure and shortfalls of first generation C2IS.
8. Traditional requirements analysis does not pertain to IT.
9. How do we adapt/adopt COTS/GOTS/MOTS and other OTS systems to our unique CF requirements?
10. C2IS exposure and understanding CF-wide.
13. Requirements capture and methodology.
18. Collect what allies are doing and see what their successes and failures are.
23. Get the best 80% in the 80/20 solution.
24. What is technically possible now and in the future?
25. What is technically supportable now and in the future?
26. Technical abilities to do something does not make it a requirement.
34. How much information is there really?

Requirements Capture: Information needs

1. Good interface between system user, and developers
2. An understanding of the environment in which the system is to operate
3. Information needs are hard to determine - would be described by the user & include specific capabilities, interoperability, etc.
4. What systems have worked/failed

5. Are there automated methods for data capture?
6. Show the user a system to elicit user feedback

Requirements Capture: Creative solutions

1. Co-locate users & developers at least temporarily
2. Users aid in prototype
3. Use networking for collocating users and developers
4. Implement multi-media solutions for collocating
5. Implement a reporting mechanism through which the user can describe changing requirements as the system ages.
6. Expose developers to operational environment
7. Solicit input from only lowest level users, not managers/decision makers

Requirements Capture: Benefits

1. Implemented system will reflect the real need of the user
2. Unsatisfied requirements will be captured for future
3. Formal system will compensate for various users to prevent requirements being skewed based on a small set of users.
4. Use of graphical user requirements capturing will minimize development + allow for near-real time user input (Remember that mil user may only be in position for 2-3 years!)
5. Modified requirements capture will be well suited to it
6. Requirements can be better prioritized
7. Trade-offs between conflicting requirements can be resolved

Requirements Capture: Problems

1. Posting cycle of users or key personnel
2. Scientists work in isolation from users and like to pursue their pet projects
3. Requirements capture methodology is not a formal process and can easily go off track.
4. User may not be interested/available to provide their requirements
5. User requirements that are captured may not represent the overall requirements of all users
6. Proper user requirements capture requires lots of time from users who already are overloaded
7. Ease of providing requirements - more changes requested, prioritization / cost

Requirements Capture: Gut feeling

1. Taking users away from "real" job
2. Developers may not understand current operational environment which users take for granted
3. Will work because it defines solution to a problem
4. Yes
5. Yes if users & developers work together in a formal system
6. Yes if will is there to work plan properly
7. Yes but user/developer interface must be very carefully maintained.

CONCEPT E: OPERATIONAL RESEARCH

14. Ways to predict impact on other operations.
16. Measure effectiveness of C2 system.
31. OR critical in payback analysis.

Operational Research: Information needs

1. What role can OR play? Pay back analysis
2. Integration with other functions involved in C2 process
3. Impact of OR on doctrine (and vice-versa)
4. What can OR do to speed the C2 process? Info is needed

Operational Research: Creative solutions

1. Integrate OR into formal life cycle process
2. Make OR & R&D responsive to users by giving user the financial control over some of their efforts
3. Distribute widely OR models for users first cut at problems
4. Have posting of an OR scientist at labs
5. Educate & train an operator (military) after a career of experience in the field (not a general, maybe a senior captain or major)

Operational Research: Benefits

1. OR provides inexpensive way of assessing '80%' solution
2. Establishes rapport between users and developers
3. Get biggest bang for buck
4. Help build case for new/improved capabilities
5. Educate CF on advantage of OR for future problem-solving
6. OR might provide solution for several related problems
7. Proper OR should result in most effective operator use of system

Operational Research: Problems

1. Requires money that could be spend on other DND needs
2. High tech solutions might be offered when low tech will work fine
3. Ops researchers might not always be able to keep up with rapid changes in system development - might produce research on systems which are already almost obsolete
4. Wide tool availability - "misuse" of models
5. OR staff not interested in getting close to user

Gut feeling

1. May not be important
2. Increased importance to build case for resources to improve system
3. Yes, this is the better way of developing a solution
4. Maybe
5. Maybe - ops research needs a much more extensive interface with the user.

CONCEPT F: DATA/INFORMATION/KNOWLEDGE CAPTURE

12. Information support to handle information fusion/ correlation/ fitting.
20. Automated decision making (e.g., Co-operative Engagement Capability) - how far do you go?
32. Studying concepts of information ageing.
33. Conversion of information into knowledge.
35. Who needs what/ when? (information requirements)

Data/... Capture: Information needs

1. What data/info do operators need?/when?
2. How do we produce knowledge? Who decides what's knowledge?
3. How can we measure "information ageing?"
4. When do you archive data? What data?
5. How do you filter information - what are redundant bits?
6. What level of command needs what information - info needs of platoon Commander vs. Division Commander is different? Who determines who needs what?
7. Need to develop information exchange requirements
8. Should training be general or specific (generic vs. specialized systems)?

Data/... Capture: Creative solutions

1. Team approach - users, scientists, engineers working together

2. Doctrine testing unit in doctrine development unit
3. Automated method of capturing data from operational system
4. Develop specialized training for selected individuals to become "info experts"
5. Develop methods by which "confidence factors" can be attached to pieces of information.

Data/... Capture: Benefits

1. Knowledge which is properly distributed and displayed will give commanders a much better appreciation of the battlefield
2. By properly treating all input information, the load on users can be reduced, saving them stress and improving reaction times
3. By pre-processing data as far forward as possible, less stress on infrastructure
4. Better quality data = better decision making
5. Faster availability of data = faster decision making
6. Better use of personnel

Data/... Capture: Problems

1. Will require more time to get to a solution
2. Complexity of what to capture/collect makes it difficult
3. May not capture correct data
4. Spend too much time capturing info and not enough solving problem
5. Filtering eliminates data - risk of missing important bits
6. More processing = more time before data is available
7. Commanders may not be aware of impact of data filtering on what info is presented
8. Do commanders have confidence in machines making decisions?
9. Passing info: communications limitations
10. Info overwhelm: too much info, screen too crowded
11. Reluctance to learn/computer literacy by users - (comment at CFB Gagetown: do you mean I will have to learn to type?)

Data/... Capture: Gut feeling

1. Maybe
2. Only way to cope with increasing amount of info
3. Yes, if not, commanders will be drowned by information overload
4. Depends on attitude of commander/decision maker - if conventional decision maker, then no, if open to genesis of new decision making models, then yes

5. Yes, must change methods to prevent info overload

CONCEPT G: FIELDING

2. User as a developer in the C2 process.
3. Evaluate failure and shortfalls of first generation C2IS.
9. How do we adapt/adopt COTS/GOTS/MOTS and other OTS systems to our unique CF requirements?
17. Primacy of time limited vs. complete solutions.
19. Interoperability - what changes can be built into the system to accommodate the future?

Fielding: Information needs

1. Info on COTS/MOTS/etc. Readily available
2. Need to evaluate system after fielding with appropriate time
3. Identify users completely and continuously
4. Identify how & where users & developers can see each others environments
5. Collect evaluations of C2IS
6. What are the issues re fielding if evolutionary systems? How to resolve
7. User training/acceptance

Fielding: Creative solutions

1. Evolutionary approach to fielding systems. Implement 80% and add to capability with next implementation.
2. Put implementers/designers in field with user
3. Designate units as prototyping to test out new equipment
4. Have scientists participate in field exercises
5. Field developers to evaluate system in use
6. Register users
7. Move selected R&D scientist to user location for 1-2 years to ensure good "user/developer relationship" and allow for rapid prototyping. "user as a developer. Developer as a user"
8. Train a civilian technologist to do a military operator's job

Fielding: Benefits

1. Improves efficiency, saves money, uses less people
2. Ensures follow-on projects benefit from previous successes & failures
3. User gets a partial solution sooner

4. A more timely implementation means user's needs have not changed
5. System being implemented has more current technology
6. Fielding is based on building on previous version which reduce user training (only training on changes) and increases user acceptance
7. No loss of current functionality
8. No large change to support environment, etc.

Fielding: Problems

1. System might not be robust enough for military service if COTS technology used
2. Systems which are changing incrementally will be a configuration management nightmare, raising logistical, compatibility & repair problems.
3. Inbred distrust of users & developers increases on failure
4. Partial solution may not satisfy the requirement
5. Part not implemented may be the most important
6. CF like to "initiate" US by purchasing their systems (one good reason however, is interoperability): why develop our own? Does CF requirements = US requirements?
7. Use of COTS: problems of ruggedness service (repair/parts) in the field, future support
8. Reliance on US system means reliance on US fielding
9. COTS - lack of control of software/system. Manufacturer can change system at will and stop supporting all or part of system requiring a change

Fielding: Gut feeling

1. Yes if we want to meet user requirements/needs
2. Yes if we have user support and we deliver
3. Yes trying to implement the entire system has never worked well
4. Yes but must be willing to pay cost
5. Yes, must field systems faster, cheaper & with better capability
6. Yes, people want to be involved with a solution to their problems, not jut told "do it"

PRIORITIZATION

VOTING SUMMARY

	P1	P2	P3	P4	P5	P6
A. Life cycle process modification	6	5	3	1	6	1
B. Performance modelling/Development Lab	4	2	1	1	3	4
C. Feedback	2	4	1	1	2	7
D. Requirements capture	3	3	2	1	1	3
E. Operational Research	5	8	5	4	7	8
F. Data/Information/Knowledge capture	6	7	4	3	3	5
G. Fielding	1	1	1	1	4	6
H. System engineering[1]	7	6	3	2	5	2

AVERAGE RANK

	Average Rank
A. Life cycle process modification	3.7
B. Performance modelling/Development Lab	2.5
C. Feedback	2.8
D. Requirements capture	2.2
E. Operational Research	6.2
F. Data/Information/Knowledge capture	4.7
G. Fielding	2.3
H. System engineering	4.2

[1] Systems engineering (Concept H) was combined with Life cycle process modification (Concept A) by the syndicate after the vote. This did not affect the analysis.

SYNDICATE 1D: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN ANALYTICAL METHODS FOR COMMAND AND CONTROL

INTRODUCTION

D-1. Syndicate 1D was asked the same question as Syndicate 1C:

> **"What operational research and systems analysis are required and what opportunities do they provide, to support the CF during the complete life-cycle of C2IS?"**

This syndicate went through the process of Idea Generation and Concept Grouping, then Concept Development and Prioritisation. The syndicate developed 32 ideas which were grouped into the following four concepts:

a. Requirements;

b. Evaluation methods;

c. Development (Design/Build); and

d. Doctrine.

D-2. The following format is used in documentation. For each concept:

a. Idea base for each concept (generated via Nominal Group Technique);

b. Idea development for each concept (generated via Six Thinking Hats):

(1) Information needs;

(2) Creative solutions;

(3) Benefits;

(4) Problems; and

(5) Gut feelings;

c. Prioritization (anonymous syndicate member votes).

D-3. Voting results were tabulated. Results and average rankings appear at the end of this annex. This syndicate assessed concepts in the following approximate order of priority:

a. Evaluation methods (Concept B);

b. Requirements (Concept A);

c. Development (Concept C); and

d. Doctrine (Concept D).

IDEA INVENTORY

1. Evolutionary iterative approach
2. Information requirements at each level
3. Evaluation models and frameworks
4. Performance monitoring
5. Historical review/evaluation
6. Framework for training development
7. Information transfer techniques
8. Hierarchy of measures of effectiveness/performance
9. System vulnerability/threat assessment
10. Operator-in-the-loop at all stages
11. Standards in evaluation
12. Redundancy in information paths
13. Fit command structure with technology

14. Assessment of levels of information required
15. Optimal integration of information
16. Assess world-wide research and development
17. Assess impact to mission effectiveness
18. Quality and timely feedback
19. Quantify dynamics of information flow
20. Simulate changes
21. Investigate source input and complexity levels
22. Distributed interactive simulation
23. Information availability
24. Effective information presentation
25. Improve C2 evaluation methods
26. Conflict resolution in data fusion
27. Evaluation of failure modes
28. Identification of areas of maximum opportunity
29. Evaluation of appropriate information processing
30. Evaluation of information availability and presentation
31. Evaluation for requirement for backup systems
32. Define research scope

CONCEPT A: EVALUATION METHODS

1. Evolutionary iterative approach
3. Evaluation models and frameworks
4. Performance monitoring
5. Historical review/evaluation
8. Hierarchy of measures of effectiveness/performance
9. System vulnerability/threat assessment
10. Operator-in-the-loop at all stages
15. Optimal integration of information
16. Assess world-wide research and development
17. Assess impact to mission effectiveness
18. Quality and timely feedback
19. Quantify dynamics of information flow
20. Simulate changes
21. Investigate source input and complexity levels
22. Distributed interactive simulation
24. Effective information presentation
25. Improve C2 evaluation methods
26. Conflict resolution in data fusion
27. Evaluation of failure modes
28. Identification of areas of maximum opportunity
29. Evaluation of appropriate information processing

30. Evaluation of information availability and presentation
32. Define research scope

Evaluation Methods: Information Needs

1. Model frameworks
2. Historical context & perspective
3. Mission understanding
4. Operators perspective & feedback
5. Command structure
6. Technology trends - scope of R&D world wide
7. Tools for simulation
8. MOP, definitions
9. Criticality
10. Funding support levels
11. Environmental conditions - threat
12. Level of completeness - fidelity
13. Access to req./verified operational data
14. Timing & timeliness

Evaluation Methods: Creative solutions

1. Battle labs - teaming approach (operators, scientists, engineers)
2. DIS (distributed information systems) approach
3. Access to advanced data collection systems
4. New analytical tools & paradigms e.g. Fuzzy logic vs. probability /statistics neural nets
5. Modular
6. Automated test tools
7. Involve R&D scientists in evaluation process

Evaluation Methods: Benefits

1. Cost & time savings throughout life cycle
2. Rapid delivery of validated system
3. Operator confidence in system
4. Benefits Canadian industry foreign sales
5. Aids in developing new doctrine
6. System that meets current & future needs
7. Potential for continual monitoring of performance
8. Better linkage between operators & scientists - trust & confidence factors
9. Validate operational methods/requirements

Evaluation Methods: Problems

1. Loss of life
2. Inappropriate concentration of resources
3. Misemployment of tool
4. System not used
5. Wasted money
6. Poor decision making/mistrust
7. Unnecessary enhancements to "correct" non-existent problems
8. Limits usefulness of operator/system feedback
9. Lead to development of competing or duplicate capabilities
10. Slows down evolution of system capability
11. May lead to inappropriate training
12. Concentration on present operational requirements rather than those of the future
13. Poor application of evaluation results to CF operational needs - credibility problems

Evaluation Methods: Gut feeling

1. Systems evaluation is essential to ensure systems are used properly and functioned accordingly to design specifications
2. High priority for OR - no one else can do it
3. As indicated by the large number of ideas placed in this category, evaluation is a cornerstone to success
4. Better system and requirements evaluation methods can provide big increase in capability for relatively low cost
5. The design, development & evaluation of systems is one of the most cost effective ways to increase the ultimate credibility of the CF. However the choice of which requirement to address requires careful evaluation of Canadian vs. foreign industrial capabilities
6. Systems evaluation critical
7. We must be pragmatic in our R&D efforts relating to evaluation. Some areas such as human performance in C2IS is beyond our capability to effectively model for evaluation purposes. The battle lab approach is a more effective near to midterm method for evaluating human interaction. A detailed definition of the mission scenarios, for evaluation of C2IS effectiveness is important & must be done

CONCEPT B: REQUIREMENTS

1. Evolutionary iterative approach
3. Evaluation models and frameworks

4. Performance monitoring
5. Historical review/evaluation
8. Hierarchy of measures of effectiveness/performance
9. System vulnerability/threat assessment
10. Operator-in-the-loop at all stages
15. Optimal integration of information
16. Assess world-wide research and development
17. Assess impact to mission effectiveness
18. Quality and timely feedback
19. Quantify dynamics of information flow
20. Simulate changes
21. Investigate source input and complexity levels
22. Distributed interactive simulation
24. Effective information presentation
25. Improve C2 evaluation methods
26. Conflict resolution in data fusion
27. Evaluation of failure modes
28. Identification of areas of maximum opportunity
29. Evaluation of appropriate information processing
30. Evaluation of information availability and presentation
32. Define research scope

Requirements: Information Needs

1. Identify users
2. Missions of users
3. User inputs & outputs
4. Operational - doctrine, orders, sensors, intelligence
5. Non-operational - logistics, engineering, support
6. Information requirements in command structure
7. Releasability/interoperability issues
8. Acceptable level of risk
9. Impact of status quo
10. C2 decision process (may be operational doctrine)
11. Current/future technology trends
12. Life cycle cost/supportability of new technology

Requirements: Creative solutions

1. Broad review of all ongoing R&D activity
2. Surveys of international/allied C2 programs
3. Develop process to improve effectiveness of definition of operational requirements by operators

4. Rapid prototyping tools are available to capture requirements
5. Recent examples from conflicts, to refine requirements - Bosnia, Gulf, etc.
6. Closer contact of scientists with operators to enable better requirements capture
7. KISS (keep it simple)
8. Requirements tracking database

Requirements: Benefits

1. Reducing cost & effort
2. Reducing feature creep - appropriate technology, no gold plating
3. Getting what we need, not what we want
4. Increased operational effectiveness (lethality)
5. Improved system support
6. More focus to R&D program
7. More rapid development of fielded systems
8. More effective CF?

Requirements: Problems

1. Too much time spent in defining requirement
2. Not keeping up with rapidly evolving "battle space"
3. Requirements process imposing solutions
4. Inappropriate requirements for Canada (driven by US initiatives)
5. Useless system (ineffective) solved wrong problem
6. Wasted money/effort
7. Lack of confidence in system, information
8. Poor requirements delay project phases/funding
9. Process encourages requirements creep
10. Operators spend too much time defining requirements & not enough performing operations

Requirements: Gut feeling

1. Driving factor (can't arrive at proper destination if you start on the wrong road!)
2. By far most N.B. category, but along with doctrine the most difficult part of systems analysis to do effectively
3. Clear system/operators requirements definition is the first step in any system development/buy
4. In a rapidly evolving environment, this must be handled carefully. Requirements can become obsolete almost before they are written down

5. The starting point for any endeavour, however, we must avoid analysis paralysis
6. Requirements analysis needs to be continuous process
7. Requirements must evolve on a continuing basis and must be more closely linked with R&D program and technology trends.

CONCEPT C: DEVELOPMENT (DESIGN/BUILD)

1. Evolutionary iterative approach
7. Information transfer techniques
10. Operator-in-the-loop at all stages
12. Redundancy in information paths
13. Fit command structure with technology
15. Optimal integration of information
16. Assess world-wide research and development
18. Quality and timely feedback
19. Quantify dynamics of information flow
20. Simulate changes
22. Distributed interactive simulation
24. Effective information presentation
26. Conflict resolution in data fusion
27. Evaluation of failure modes
28. Identification of areas of maximum opportunity
29. Evaluation of appropriate information processing
32. Define research scope

Development: Information Needs

1. What is requirement
2. Time frame prototype/final system
3. Resources available
4. Doctrine
5. C2 structure
6. Technology trends
7. User feedback
8. What parts of solution are available elsewhere (COTS)
9. Military specific features - non COTS
10. Canadian specific features non US
11. Simulation tools
12. Architecture alternatives
13. Brain pool
14. Test tools/infrastructure
15. Automated tool (CASE)

Development: Creative solutions

1. Modular responsibility (Canada, US, UK, etc. develop specific modules)
2. Cost sharing (as above)
3. Small development blocks - short development period (Lego approach)
4. Partnering with industry and universities
5. Investigate new COTS products for C2IS application
6. Question requirement/restate requirement
7. Evolutionary approach (deploy modules)
8. Investigate human/machine paradigm
9. Advanced S/W development environments (OOD)
10. Enables rapid design/build/test cycle

Development: Benefits

1. Potential cost and time savings
2. Staying up-to-date with rapidly changing field; allies and adversaries are doing anyway
3. Better match to changing missions
4. Importance of adapting COTS to military requirements - better find product
5. Higher supportability efficiency
6. Decreased re-training issues
7. Rapid fielding of systems
8. Better use of limited operation staff
9. Technology push opportunities

Development: Problems

1. Potential for wasted effort & time
2. Lack of discipline in applying development process may result in "moving requirements"
3. Insufficient resources resulting in late delivery
4. Staying too long with "previous-generation" technology - obsolescence inevitable
5. Choosing the wrong technology (S/W, platform)
6. The enemy is more effective than you
7. Not fielded in time
8. Canadian industry non-competitive - lost revenue
9. Public disapproval of DND decisions

Development: Gut feeling

1. Limited potential/benefit for applying new R&D effort, but can benefit from effective use of analysis tools to improve system design
2. R&D must be based upon solid requirements and a good understanding of risk/reward
3. Must work closely with operators
4. A careful assessment of relevant technologies for best solutions to operational requirement is the R&D challenge
5. R&D might focus on adapting existing technologies (COTS) to CF rather than developing completely new systems (more cost/time effective)
6. There must be some portion of the development resources applied to new research ideas; COTS "solutions" are intended for general broad-based application and may not be well-tailored to military needs
7. If the engine doesn't work the plane; ship; or tank won't fly; sail; run

CONCEPT D: DOCTRINE

5. Historical review/evaluation
6. Framework for training development
13. Fit command structure with technology
16. Assess world-wide research and development
19. Quantify dynamics of information flow
26. Conflict resolution in data fusion
29. Evaluation of appropriate information processing

Doctrine: Information Needs

1. Interoperability scope/priority
2. Pervasiveness in organization
3. Access: levels/ranks/persons
4. Priority not implementation/capital acquisition
5. C2 structure
6. International affairs/threat/commitment
7. Force capabilities
8. Technology trends, impact on doctrine
9. Comparative doctrines - other nations
10. Impact on training requirements
11. Methods to test for weaknesses

Doctrine: Creative solutions

1. Time of transition therefore, good opportunity to change doctrine

2. Downsizing - vested interests are diminished
3. Technological evolution is very fast therefore opportunity to exploit latest tools and to enable flexible doctrine
4. Nature of threat is very different therefore demands new procedures
5. Decisive leadership
6. Acceptance of "good enough"
7. Erosion of intra-service barriers (jointness)
8. Globalness
9. Adapt non-tradition military experience (peace-keeping, humanitarian relief)
10. Model doctrine & technology & assess impact of changes in each

Doctrine: Benefits

1. Mission effectively matches national, international, & CF objectives
2. Mission activities more efficient
3. Lower risk to personnel
4. Frees commanders for more creative command
5. Clear direction
6. Achievable goals
7. Better application of limited resources - focus effort
8. Improved guidance/look ahead for R&D thrusts
9. Reduced system design errors
10. Better defining of requirements

Doctrine: Problems

1. Doctrine errors negatively impact requirements and system design
2. Takes resources from delivery operational capability
3. Restricts use of GOTS products from other forces
4. Bad doctrine weakens CF defence capability
5. Limit interoperability
6. Difficult to model (or predict) effects of doctrinal changes - the risk is that the new system may be less effective than the old
7. Resistance to change may negate effective R&D
8. May lead to doctrinal "tinkering" and total breakdown in effectiveness
9. Inappropriate reliance on new technology may endanger personnel - bad press
10. Training problems - how to implement new doctrine
11. Achieveability (realism)
12. Inflexibility
13. Misinterpretation

Doctrine: Gut feeling

1. Most ideas captured are relevant but we may have overlooked some
2. Big pay-back in applying op research to CF doctrine
3. If this is not correct we are all in trouble - large potential negative impact
4. Need to be open-minded & evolve doctrine as technology & world politics change. (however, I am not optimistic)
5. This is the most difficult area to make progress due to resistance to change by commanders and difficulty capturing doctrine effectively through hierarchical and technological changes/improvements. Considerable opportunity to waste time & money with little gain
6. This is an area where potential for wasting time and resources is high, but it is essential to establish a doctrine (which facilitates standardization within CF)
7. Doctrine doesn't evolve in the abstract; it comes from experience with best and worst practice. Can one really do R&D on doctrine?

PRIORITIZATION

VOTING SUMMARY

	P1	P2	P3	P4	P5	P6	P7	P8
A. Requirements	1	4	2	1	3	2	2	1
B. Evaluation	3	3	1	2	2	1	1	2
C. Development	2	2	4	3	1	3	4	3
D. Doctrine	4	1	3	4	4	4	3	4

AVERAGE RANK

	Average Rank
A. Requirements	2.0
B. Evaluation	1.9
C. Development	2.8
D. Doctrine	3.4

SYNDICATE 1E: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN INFORMATION SYSTEMS FOR COMMAND AND CONTROL

INTRODUCTION

E-1. Syndicate 1E was asked the following question:

"What R&D in information systems is required, and what opportunities exist, to support the CF during the complete life-cycle of C2IS?"

This syndicate went through the process of Idea Generation and Concept Grouping, then Concept Development and Prioritisation. The syndicate developed 46 ideas which were grouped into the following six concepts:

a. C2 warfare;

b. Information and knowledge management;

c. Information requirements;

d. Integration issues;

e. Automated aids/ fusion; and

f. Systems issues.

E-2. The following format is used in documentation. For each concept:

a. Idea base for each concept (generated via Nominal Group Technique);

b. Idea development for each concept (generated via Six Thinking Hats):

(1) Information needs;

(2) Creative solutions;

(3) Benefits;

(4) Problems; and

(5) Gut feelings;

c. Prioritization (anonymous syndicate member votes).

E-3. Voting results did not appear to indicate group consensus. The data was also analyzed using a computer-based consensus analysis program. A statistically significant degree of consensus was *not* found. Voting results and average rankings appear at the end of this annex.

IDEA INVENTORY

1. Avoid rigid rules.
2. Knowledge-based system.
3. Information in Joint Ops.
4. Information fusion of data.
5. Workload & flow balancing.
6. Methodologies of storing & packaging data.
7. Essential elements of info requirements.
8. Situational awareness.
9. Global C2IS architecture.
10. Improve inter-operability.
11. Sensor development/compatibility.
12. Exploitation of COTS/GOTS.
13. Capture user's data requirements.
14. Security of info systems (firewall).
15. Security of data.
16. Spatial & temporal database management.
17. Decision aids/support.

18. Systems integration.
19. Smart systems for info pull.
20. Development of info standards.
21. Operator impact on info systems.
22. Reverse engineering for releaseability.
23. Alternatives to Process driven.
24. Networking capabilities and requirements.
25. Requirement capture /engineering.
26. Intelligent presentation of info
27. Presentation of non-visual data.
28. Simulation of info systems.
29. Design of info systems to ensure evolutionary growth is possible.
30. Data archiving rule sets.
31. Better ways of encapsulating data.
32. Hardware modularity & supportability.
33. Quality of information.
34. Rapid delivery.
35. Extension of info from strategic to tactical.
36. CM & CCM.
37. Real-time.
38. Truth maintenance.
39. Measures of effectiveness/performance/training.
40. Handling non-standard data (e.g. voice).
41. Information compression & representation.
42. Commercial-standard software philosophy.
43. Data utility/relevance.
44. Software engineering methodology.
45. Graceful Degradation.
46. Avoid doctrinal constraints.

CONCEPT A: C2 WARFARE

14. Security of info systems (firewall).
15. Security of data.
36. CM & CMM.
46. Avoid doctrinal constraints.

C2 Warfare: Information Needs

1. Enemy's information order of battle
2. Policy wrt IW
3. Own vulnerabilities
4. Characteristics of enemy IS

5. Doctrine
6. Intentions (own/enemy)
7. Security requirements
8. Logging/journal of transactions
9. Information holding requirements
10. Level of scenario recording/reply
11. Simulation of scenarios
12. Operational parameters boundaries

C2 Warfare: Creative solutions

1. Create a CCW testbed to try protective & offensive strategies
2. Simulation of our info systems to assess vulnerabilities/strengths, and protection strategies
3. Industry participation
4. Focused intelligence on commercial networks (National/Foreign)
5. Op Research analysis of activities
6. Simulation

C2 Warfare: Benefits

1. Protection of IM resources
2. Destruction of enemy IM resources
3. Non destructive engagement (short of war)
4. Combat multiplier
5. Enhance decision cycle
6. Easier identification of weak points
7. Improved robustness
8. Further refinement of requirements
9. Capture design deficiencies early
10. Enables teamwork between operators and R&D
11. Explore wide range of variables

C2 Warfare: Problems

1. Virus universal
2. Pirates/Mafia/terrorists
3. Systems to complex with too many security measures to operate
4. Misunderstanding of fundamental: security by user
5. Losing underlying effectiveness due to too much security layering
6. Hard to get policy direction
7. Is IW attack an act of war?
8. Sensitivity of issue makes industry involvement difficult

C2 Warfare: Gut feeling

1. Very important area, but practical security issues will make it difficult to carry out
2. Not a short term, low cost project
3. Must stay abreast with most recent development
4. Protect National
5. Not well understood area
6. Required R&D effort but difficult to get (security)
7. Need training to understand it
8. Much needed as enemy's C2 improves

CONCEPT B: INFORMATION AND KNOWLEDGE MANAGEMENT

2. Knowledge-based system.
6. Methodologies of storing & packaging data.
9. Global C2IS architecture.
10. Improve inter-operability.
16. Spatial & temporal database management.
19. Smart systems for info pull.
20. Development of info standards.
23. Alternatives to Process driven.
24. Networking capabilities and requirements.
26. Intelligent presentation of info
30. Data archiving rule sets.
31. Better ways of encapsulating data.
33. Quality of information.
38. Truth maintenance.
40. Handling non-standard data (e.g. voice).
41. Information compression & representation.
43. Data utility/relevance.
46. Avoid doctrinal constraints.

Information and Knowledge Management: Information Needs

1. Survey of existing procedure & concepts
2. Info architecture
3. Data/information/knowledge model
4. Tools for storage, management, distribution
5. Semantic integration
6. Model
7. Archiving strategies

8. Schemes for truth maintenance
9. Scenario development

Information and Knowledge Management: Creative solutions

1. Simulation
2. Standard tactical databases
3. Create a dialogue with commercial industry and universities
4. Exploit civilian developments to solve military problems
5. Testbed for knowledge management concepts, rapid prototyping
6. Architecture/structure
7. Fusion
8. International effort (I3 effort)
9. Alternative data stores
10. User trials
11. Determine levels of data overload
12. Examine alternative data displays

Information and Knowledge Management: Benefits

1. Human/machine interface improvement
2. Improved timeliness
3. Faster more accurate decision cycle
4. Improves user input
5. Improve flexibility
6. Gives broad awareness of COTS/GOTS capabilities
7. Reduce cost & risks
8. Improves interoperability
9. Enlightened decision making
10. Basis for sharing info/knowledge
11 Info sphere
12. Reduction in application development resources (reusability of IM resources)
13. Improved information management
14. Improved system performance

Information and Knowledge Management: Problems

1. Cost of simulation
2. How to validate simulation results
3. Limited availability of tactical data bases
4. Complexity of the system
5. Cultural requirements to adhere to standards

6. Data overload
7. Cost
8. Incorrect conclusion from incomplete data
9. Development of blind faith on IS
10. Higher co-ordination cost
11. Longer schedule
12. Civilian development may not meet all mil needs

Information and Knowledge Management: Gut feeling

1. Important area required high R&D involvement
2. Still unsure of topic details (too generic)
3. What does this mean?
4. Will the commercial world solve the problem (in large corporations)?
   Critical foundation for any C2IS system

CONCEPT C: INFORMATION REQUIREMENTS

3. Information in Joint Ops.
4. Information fusion of data.
7. Essential elements of info requirements.
13. Capture user's data requirements.
21. Operator impact on info systems.
25. Requirement capture /engineering.
43. Data utility/relevance.
46. Avoid doctrinal constraints.

Information Requirements: Information Needs

1. Timeliness, real-time
2. Level of info required (tactical/formation/strategic
3. Amount of relevance of info
4. Accuracy
5. Releasibility of allied info
6. Method for info capture
7. Methodology
8. Foreign data/info models
9. Doctrine (foreign/national)
10. Sea, land, air, joint

Information Requirements: Creative solutions

1. Rapid prototyping

2. Battle lab
3. Distributed test bed in the users
4. Constant liaison
5. Simulation & testing - including external/sensors
6. Field & replace (evolutionary development)
7. Buy & try (COTS/GOTS)
8. Joint & combined demonstrations (JWID type)
9. DS/analyst as part of each J3 staff to observe/articulate issues
10. Connection to allied simulation systems
11. Distributed interactive simulation capability
12. OSD's - operational sequence diagrams

Information Requirements: Benefits

1. Early/easy failures
2. Reduce risks-technical, schedule, performance
3. Minimize cost
4. Better understanding of requirements
5. Allows for incremental refinement of requirements
6. User involvement from the start
7. Avoid making the same mistakes, allies may have already made
8. Leverage of developments of allies
9. System that fulfil operator's needs
10. Permits doctrine changes to take advantage of automation
11. More responsive to changing requirements

Information Requirements: Problems

1. User overtasked/unable to participate
2. Evolution of system outpacing training
3. Change in direction by allies
4. No fundamental research
5. Tend to use R&D as the solution
6. Hard to get definition of requirements
7. Doctrine based on manual systems
8. Try to capture everything
9. User requirement constantly changes in testbeds/battle labs

Information Requirements: Gut feeling

1. Very, very, very important
2. Most important but hard to quantify/grasp
3. Difficult R&D involvement

4. Starting point that puts framework on problem
5. Has been the problem of many developments
6. Important to get the info requirements correct at the start
7. Difficult to attack due to rapid changes

CONCEPT D: INTEGRATION ISSUES

10. Improve inter-operability.
12. Exploitation of COTS/GOTS.
18. Systems integration.
20. Development of info standards.
24. Networking capabilities and requirements.
26. Intelligent presentation of info
35. Extension of info from strategic to tactical.
46. Avoid doctrinal constraints.

Integration Issues: Information Needs

1. Interfaces
2. Architectures - operational - information
3. Information model, knowledge model, information distribution
4. Technical
5. Standards
6. Support strategy
7. Releasbility of allied info
8. Replicated/distributed databases
9. Sensors/IS compatibility
10. Standards vs. specific hardware
11. Survivability
12. Fault tolerance
13. Consequence of maintaining status quo

Integration Issues: Creative solutions

1. Testbed (Battle Lab - all items)
2. Evolutionary fielding à la France - Fielded V1, Test V2, Research V3
3. Product-based standards
4. Complete common arch
5. Use API's
6. Develop data model & simulation
7. Develop standard interfaces
8. Common operating environment
9. Develop integration standards

10. Develop integration test procedures
11. Collaborate with Allies on portions of the same system

Integration Issues: Benefits

1. User feedback (involvement)
2. Portability
3. Interoperability (improved/enhance possibilities)
4. Avoids high one time costs
5. Improved responsiveness
6. Flexibility to adjust
7. Reduce risk in technical, cost
8. Integrated environment
9. Maximize utility of COTS/GOTS
10. Fully interoperable system and reduced cost
11. Reduced cost, better mission area apps
12. Permits co-existence of legacy and new systems
13. Enables systems integration in a controlled environment
14. Facilitates training

Integration Issues: Problems

1. Risk of too large scope - cost
2. Too narrow focus on issues
3. Co-ordination problems during development.
4. Failure to keep API's backward compatible
5. Tends to focus on a limited set of solutions
6. Moving target for external systems
7. Integration not an R&D issue?
8. Very large/complex system to cope in the small problems
9. Complexity of software development configuration

Integration Issues: Gut feeling

1. Software engineering problem not really R&D issue?
2. Hope this automates/eliminates some work so can spend time on monitoring/assessing
3. Very important for implementation
4. Requires diligence in S/W engineering, but not R&D
5. Fundamental for effective/robust fielding

CONCEPT E: AUTOMATED AIDS/ FUSION

1. Avoid rigid rules.
2. Knowledge-based system.
4. Information fusion of data.
8. Situational awareness.
11. Sensor development/compatibility.
17. Decision aids/support.
19. Smart systems for info pull.
26. Intelligent presentation of info
27. Presentation of non-visual data.
33. Quality of information.
34. Rapid delivery.
37. Real-time.
38. Truth maintenance.
45. Graceful Degradation.
46. Avoid doctrinal constraints.

Automated Aids: Information Needs

1. Existing rule sets
2. MOPs
3. Composition of user community/operators
4. Availability of statistics
5. Characterization of cognitive processes
6. Requirements for timeliness, intelligibility
7. Battlefield scenarios
8. Organic/non-organic sensors
9. Knowledge structure/organization
10. Doctrine/SOPs
11. Special/temporal data base management
12. Data/info fusion
13. Info reliability

Automated Aids: Creative solutions

1. Develop standards for timeliness
2. Develop overall logical architecture
3. Labs to try ideas
4. Simulation/LiveEX to trial ideas
5. Use multi-sensor data fusion
6. Integrated into overall C2 sustainability.
7. Distributed testbed (labs, operators, battlelabs)
8. Joint exercises
9. Multi-national

10. Try to bring commercial ideas of virtual reality to visualization problem

Automated Aids: Benefits

1. Testbed allows assessment of value of concepts
2. Commercial industry much larger source of ideas
3. The exercises involve operators
4. Can explore larger range of situations with simulation
5. Reduced decision cycle/better decision
6. Situational awareness
7. Combat multiplier
8. Global picture
9. Protection against an action
10. Enlightened decision-making
11. Produces a tactical picture that can be trusted

Automated Aids: Problems

1. May solve the wrong problem
2. May confuse the issue
3. Tends to constrain you in one set of principles
4. Difficulty in modelling cognitive process
5. Expensive to get a good measure of performance
6. Reliability of information
7. Over reliance on solution
8. Non-creative ideas
9. Standard computer solutions
10. Inability to cope with extra variables
11. Locking in on wrong standard
12. Corruptive data effects
13. Developing tunnel vision towards solutions

Automated Aids: Gut feeling

1. Very important but not sure what new ideas are mentioned here
2. Fundamental to interoperability
3. Somewhere where we can leverage on commercial developments
4. Viable solutions possible
5. Vital/pay off for info System development and for reduced decision cycle.
6. Requirement understood but solution is elusive

CONCEPT F: SYSTEM ISSUES

5. Workload & flow balancing.
9. Global C2IS architecture.
11. Sensor development/compatibility.
12. Exploitation of COTS/GOTS.
18. Systems integration.
19. Smart systems for info pull.
22. Reverse engineering for releaseability.
23. Alternatives to Process driven.
27. Presentation of non-visual data.
28. Simulation of info systems.
29. Design of info systems to ensure evolutionary growth is possible.
32. Hardware modularity & supportability.
34. Rapid delivery.
35. Extension of info from strategic to tactical.
37. Real-time.
39. Measures of effectiveness/performance/training.
41. Information compression & representation.
42. Commercial-standard software philosophy.
44. Software engineering methodology.
45. Graceful Degradation.
46. Avoid doctrinal constraints.

System Issues: Information Needs

1. System description
2. System requirements
3. Interfaces with allied systems
4. Cost
5. Maintenance info
6. Architecture (core)
7. Interoperability
8. Knowledge/messaging structure
9. Human machine interface
10. Non standard I/0 devices
11. Network capabilities vs. IS requirements
12. Alternate processing
13. Growth potential

System Issues: Creative solutions

1. Open system architecture to avoid having to use on platform OS - use internet model
2. User core

3. More D than R in R&D

PRIORITIZATION

VOTING SUMMARY

	P1	P2	P3	P4
A. C2 Warfare	6	1	5	1
B. Information Management	2	2	1	2
C. Information Requirement	1	3	4	4
D. Integration	4	5	3	5
E. Automated aids/ Fusion	5	1	2	3
F. Systems issues	3	4	3	6

AVERAGE RANK

	Average Rank
A. C2 Warfare	3.3
B. Information Management	1.7
C. Information Requirement	3.0
D. Integration	4.3
E. Automated aids/ Fusion	2.7
F. Systems issues	4.0

SYNDICATE 1F: REQUIREMENTS AND OPPORTUNITIES FOR R&D IN INFORMATION SYSTEMS FOR COMMAND AND CONTROL

INTRODUCTION

F-1. Syndicate 1F was asked the same question as Syndicate 1E:

"What R&D in information systems is required, and what opportunities exist, to support the CF during the complete life-cycle of C2IS?"

This syndicate went through the process of Idea Generation and Concept Grouping, then Concept Development and Prioritisation. The syndicate developed 43 ideas which were grouped into the following nine concepts:

a. Data acquisition/ Data fusion;

b. Standards;

c. Security and protection;

d. Man-machine interface/ presentation;

e. Support (training, maintenance);

f. Decision support;

g. System acquisition;

h. Data distribution/ management; and

i. Architectures.

F-2. The following format is used in documentation. For each concept:

a. Idea base for each concept (generated via Nominal Group Technique);

b. Idea development for each concept (generated via Six Thinking Hats):

(1) Information needs;

(2) Creative solutions;

(3) Benefits;

(4) Problems; and

(5) Gut feelings;

c. Prioritization (anonymous syndicate member votes).

F-3. Voting results did not appear to indicate group consensus. The data was also analyzed using a computer-based consensus analysis program. A statistically significant degree of consensus was *not* found. Voting results and average rankings appear at the end of this annex.

IDEA INVENTORY

1. Provide sensors to create tactical picture.
2. Data fusion.
3. Protect information databases/links
4. Real-time network architectures.
5. Open architecture based on common standards.
6. Data exchange formats.
7. Scaleable systems.
8. Decision support tools (simulation).
9. Load management.
10. Automated decision making.

11. Data transfer speed.
12. Mobile networking.
13. Low/ medium/ high intensity conflict support.
14. Common algorithms.
15. Span of control.
16. Component commonality (OEM).
17. System evolution vs. replacement.
18. Peacekeeping support.
19. Wireless comms.
20. Platform independence (common interfaces).
21. Cyberwar information warfare.
22. Commercial off the shelf.
23. Belief management.
24. Information presentation.
25. Roll-up/down and information filtering.
26. Interoperability with external systems.
27. Common data dictionary.
28. Graceful degradation.
29. Distributed C2 and processing.
30. Information overload.
31. Certification.
32. Requirements capture.
33. Multi-mission support.
34. Acquisition process (departmental commitment).
35. Platform sensor errors and measurement.
36. Virtual reality.
37. Distance training.
38. Messaging.
39. Tech support: self diagnostics/ remote.
40. Configuration management - software.
41. Power sources/ generation.
42. Distributed interactive simulation.
43. Generic vs. specialized tools.
44. Real-time conferencing for collaborative analysis.
45. Input/output devices and technologies.
46. Database synchronization.
47. Security/ crypto.
48. Data compression.
49. Hardware technologies (mini, rugged, high resolution).
50. Information push/pull and system drivers.
51. GIS vs. map viewers.
52. COE vs. cost/ flexibility/ evolution.
53. Target decision making performance.

54. Data archiving.
55. Data retrieval.

CONCEPT A: DATA ACQUISITION/ DATA FUSION

1. Provide sensors to create tactical picture.
2. Data fusion.
14. Common algorithms.
19. Wireless Comms.
23. Belief management.
25. Roll-up/down and information filtering.
26. Interoperability with external systems.
27. Common data dictionary.
29. Distributed C2 and processing.
30. Information overload.
35. Platform sensor errors and measurement.
45. Input/output devices and technologies.
46. Database synchronization.
51. GIS vs. map viewers.

Data Acquisition/Data Fusion: Information needs

1. Development/improvement of sensors to provide more accurate 'picture' of operational environment
2. Take the outputs of two or more sensors and combine to obtain synergistic benefits
3. 'Picture' obtained must be compatible with external systems
4. Information produced at one level to be integrated or fused at a higher level
5. Information source traceability
6. What is the minimum information need required to exchange situation pictures at given levels of command?
7. Minimize human processes
8. Operator requirements with respect to push/pull
9. What is integrity of information acquired or to be fused
10. Can information from two data sources be fused (i.e., Are they indeed the same source)
11. Data reliability

Data Acquisition/Data Fusion: Creative solutions

1. Fuzzy logic
2. Trace data sources
3. Development of artificial intelligence to automate human processes
4. Space based radars to acquire 'big picture' with a moving target indicator (MTI) capability, place satellite in GEO
5. Consider building data fusion centres to deal with vast amount of data
6. Low probability at intercept sensors
7. Accurate sensors

Data Acquisition/Data Fusion: Benefits

1. More accurate picture from which decisions can be made, leading to less collateral damage and less possible damage to own forces
2. Better utilization of resources (both in manpower and hardware)
3. Better (quicker, more accurate) decisions (command and control)
4. Improved fighting capabilities

Data Acquisition/Data Fusion: Problems

1. Results not usable by DND - too expensive
2. Effects not fruitful - failure
3. Cannot get system to fuse data as fast or as accurately as human
4. Data formats/exchange standards not adhered to - lack of understanding by COTS (vendors and contractors)
5. Data confusion/misinformed user
6. Commonly accepted algorithms not used
7. System developed in Canada 'can't be any good'
8. Fused data less accurate than original piece

Data Acquisition/Data Fusion: Gut feeling

1. R&D in sensors and data fusion required as a fundamental input
2. R&D required to make sure we know quality of data coming in. R&D on data fusion required because a human will not be able to sort out multiple occurrences/reports of a contact in a cluttered environment and will generate many false tracks - misinformation without good data fusion
3. A critical data bottleneck
4. Need R&D to find ways to turn data into information
5. Major research requirement - how to do it, what should be fused, what should be considered but kept separate, belief maintenance of fused hypotheses

CONCEPT B: STANDARDS

4. Real-time network architectures.
5. Open architecture based on common standards.
6. Data exchange formats.
11. Data transfer speed.
14. Common algorithms.
16. Component commonality (OEM).
17. System evolution vs. replacement.
19. Wireless comms.
20. Platform independence (common interfaces).
22. Commercial off the shelf.
26. Interoperability with external systems.
27. Common data dictionary.
28. Graceful degradation.
31. Certification.
38. Messaging.
40. Configuration management - software.
43. Generic vs. specialized tools.
45. Input/output devices and technologies.
48. Data compression.
51. GIS vs. map viewers.
52. COE vs. cost/ flexibility/ evolution.

Standards: Information needs

1. NATO standards
2. UN standards
3. Like-minded nations
4. Defence industry - standards/direction (international)
5. Civilian companies' architectures
6. Choose or define a single standard to which new segments can be added to provide the required functionality
7. Interoperability is essential
8. Choice of standards for ease of upgrade due to future hardware/software improvements
9. Choice of common data for geographic systems
10. Which standards do we have at present?
11. How can standards evolve?

Standards: Creative solutions

1. Common architecture (software/hardware) standards based on interface/functionality definitions (hardware/software independence)
2. Fully industry supported standards
3. A Canadian TBMCs (COE) implementation - i.e., US standards but Canadian products
4. All COTS implementations with contracted support
5. Standard MMI symbolism, data formats, data dictionary, algorithms
6. Follow as much as possible private sector standard evolution
7. Common world-wide standard that is modular to allow for growth without changing the core
8. Standards must be evolutionary otherwise limiting

Standards: Benefits

1. Cost reduction in maintenance support
2. Cost reduction in design (development)
3. Quicker implementation
4. Interoperability free (or cheaper)
5. Shared applications
6. Cheaper hardware/software through 'quantity' buys
7. Interoperability with allies/other departments
8. More effective mission accomplishment
9. Consistency / Maintainability
10. Fewer military members, therefore each needs to cope with more and more systems; commonality and standards makes this possible
11. Operator knows what to expect
12. New applications learned quicker

Standards: Problems

1. If we become dependant on a standard and it changes for some reason then we are forced to change also
2. Standards can easily block the use of new technology
3. The best solution to a problem in one location (instance) may not be the best elsewhere
4. Lack of flexibility
5. Will acceptance of commercial standards result in a loss of operations primacy
6. Need to rewrite software if standard changes
7. The world is evolving too quickly to stick to a standard
8. Too hard and expensive to implement

Standards: Gut feeling

1. Necessary, needs to be enforced
2. Required for allied interoperability
3. Standards ensure data reliability (data capture/integrity)
4. Must keep honest broker point of view on standards in order not to fall into strict and rigid structures which may stop evolution
5. Use what's available but beyond that not so much R&D
6. Research minimum standards to get job done
7. Go with an existing standard and do research to add Canadian unique application. Without interoperability amongst formations and allies, system is extremely limited. Will also be cheaper.

CONCEPT C: SECURITY AND PROTECTION

3. Protect information databases/links
4. Real-time network architectures.
19. Wireless Comms.
20. Platform independence (common interfaces).
21. Cyberwar information warfare.
28. Graceful degradation.
46. Database synchronization.
47. Security/ crypto.

Security and Protection: Information needs

1. Cryptography techniques
2. Who can access or detect us
3. What system duplication (redundancy) do we need?
4. The threat
5. The target (if we are the ones infiltrating)
6. The impact of violation
7. Violation (security) risks
8. Security technology information
9. Multi-level secure systems (compartmented mode)
10. The security levels of the data item
11. The security levels of the users
12. The rainbow series (NSA security guides)
13. Threat potential (likelihood opponent has capability to break in)
14. Cost
15. Cyberwar techniques
16. Acquisition of threat data bases for use in decision making in C2 systems

Security and Protection: Creative solutions

1. Universal encryption algorithm
2. All information within the system could be coded to prevent a virus from entering the system
3. Fingerprint (retinal scan for access instead of user passwords)
4. Distributed database/multiple version of database to prevent/minimise effects of misinformation and viruses
5. LPI communications pathways
6. Redundant data pathways
7. Trusted pathway
8. EMP resistant networks
9. Redundant hardware

Security and Protection: Benefits

1. Ready for the C4I2 warfare age (Cyberwar)
2. Benefits to industry through technology uses
3. Improve current situation (viruses, etc.)
4. Protect national interests (banking, stock exchange, other vital information based assets) with spin-off technology
5. Marketable technology
6. Protects integrity of information and caps confidence in the products
7. Without protection there will quickly be no system
8. Concern - could effectively use false (or mis-)information
9. Provide users with confidence
10. Ability to transmit information over large distances without fear of corrupt data
11. Authorized access

Security and Protection: Problems

1. May limit capability
2. Overhead
3. Not productive unless there is a threat
4. Costly (e.g., Redundancy)
5. Time consuming (e.g. Cryptography)
6. Cost - overhead
7. Closed environment
8. Slow to get certification from security
9. Slow to evolve as new technology becomes available

10. Slow to evolve when modifications are needed because of new user requirements
11. No system can be totally secure
12. Security precautions may inhibit smooth flow of information
13. Could deny information arbitrarily from someone who needs it
14. May attract hackers

Security and Protection: Gut feeling

1. Again, necessary since without protection there may soon be no system at all
2. A necessary part of system design, research could take place in industry or university atmosphere as requirement common to commercial systems
3. Particularly necessary for military, because of requirement for information integrity. Commercial developed standards may not be robust enough for military purposes

CONCEPT D: MAN-MACHINE INTERFACE/ PRESENTATION

7. Scalable systems.
20. Platform independence (common interfaces).
23. Belief management.
24. Information presentation.
25. Roll-up/down and information filtering.
30. Information overload.
36. Virtual reality.
42. Distributed interactive simulation.
45. Input/output devices and technologies.

Man-Machine Interface: Information needs

1. User requirement
2. Information (data) availability
3. I/O device constraints/restraints (capabilities)
4. I/O device technology
5. Human factor (ergonomics)
6. MMI standards
7. System capabilities
8. System requirements
9. Data trustworthiness/system integrity
10. User capabilities
11. Symbology - standards (pictograms, figures, colours, ...)
12. Pulldown menus versus palette menus

13. Logical display of data (graphical versus numeric as an example)
14. Data filtration to prevent information overload and display clutter

Man-Machine Interface: Creative solutions

1. Interactive touch screens for easy access to information
2. Contact information embedded within contact (click on a piece of information and a window opens providing the next level of information on it. Multiple levels of information so operator can view as much or as little as desired
3. Voice activated displays, etc.
4. Configurable displays
5. 'No processing delay' interfaces
6. Multidimensional data display
7. Operator specific default screen layouts
8. Flexible display options
9. Mobile displays (I/O) (i.e., Put my screen on a monocle, and give me a glove so I can walk about and do my work!)

Man-Machine Interface: Benefits

1. Improve MMIs - more productive users!!
2. Better (quicker and more accurate) decision (command and control)
3. Better informed decisions (C2) in the same or less time
4. Improves performance in decision making
5. Less training required
6. Select filters for the task at hand
7. Lower operator workload
8. Easier to pass information with more time for other tasks
9. One person can do more - leads to potential savings in PYs and ultimate cost saving while maintaining the same capability
10. Best meet user requirements

Man-Machine Interface: Problems

1. Will each environment agree on standardized approach
2. Can military develop own systems or will the commercial solution be forced on us
3. Could take too many decisions out of the hands of people and get stupid decisions/assumptions made by a machine
4. By selecting an MMI we may rule out something that might ultimately be better
5. Users will never be satisfied

6. The commercial industry will overpower any work CRAD does (Microsoft, Sun, HP)

Man-Machine Interface: Gut feeling

1. Important; without a good interface of information to the user, the best or accurate decisions cannot be made
2. Customizable graphical user interface
3. Important to keep user in the design loop
4. Is very important but is the last thing to research. Only required once a system is ready to be fielded

CONCEPT E: SUPPORT (TRAINING, MAINTENANCE)

37. Distance training.
39. Tech support: self diagnostics/ remote.
40. Configuration management - software.
41. Power sources/ generation.
49. Hardware technologies (mini, rugged, high resolution).

Support: Information needs

1. Near real-time remote site simulation and training
2. Remote access technical support (software), self diagnosis (staff)
3. Displays - flat screen
4. What is the current level of CF computer training?
5. What multi-media course ware is available/could be designed?
6. How does Microsoft do it?
7. Money available for training
8. Cost of current system
9. Cost of current way of doing business
10. Costs of new system (PO&M)
11. LAN technology
12. Receptiveness of user to new (non-traditional) training and support concepts (distance learning vs. school house training)
13. Contractor logistics support concepts
14. Receptiveness to virtual reality training paradigm shift
15. Do we deploy some experts contractors/civilians to theatre
16. System administration/operating system standardization (UNIX versions/DOS)
17. Accountability of contractors for maintenance

Support: Creative solutions

1. Telementoring remote tutoring
2. On-line training tool (train during quiet times)
3. Simulation and training on a 'web'
4. Virtual reality display for all participants on the 'training web'
5. Fully contracted logistics support
6. Single help desk/system administrator 'networked' everywhere
7. Location independent schooling and training (realism provided by virtual reality)

Support: Benefits

1. Lower cost
2. Reduce requirement for number of people in DND/CF
3. Better reliability - less down time (availability)
4. Better trained cadre of personnel
5. Captures and refines users' requirements on the fly or as the system evolves
6. Use system to full potential
7. Reduce downtime
8. Better decisions

Support: Problems

1. Some feel operators can learn on-the-job
2. Is this approach really cost effective - is there a performance measure to determine the best approach
3. Simulation of a weapon system may not be the best way to provide operators with confidence in the system
4. Simulation must be used with the 'real thing' to provide operator confidence
5. Simulation alone will not identify all problems with a system, this is especially important with systems procured off-shore where we don't have the benefit of first-hand experience in developing the system
6. Users do not need manual/references
7. On-line help may be crashed

Support: Gut feeling

1. Training is crucial (must be done right!)
2. High system availability and support
3. Training in realistic environment is important (R&D may/will be required to reduce expenditure of expensive rounds)

4. Simulation required for training and future system development
5. Keep an investigative eye on new issues or problems to remain pro-active in this domain
6. Some R&D potential for training
7. Best and most cost effective techniques

CONCEPT F: DECISION SUPPORT TOOLS

8. Decision support tools (simulation).
10. Automated decision making.
13. Low/ medium/ high intensity conflict support.
14. Common algorithms.
15. Span of control.
18. Peacekeeping support.
21. Cyberwar information warfare.
23. Belief management.
25. Roll-up/down and information filtering.
27. Common data dictionary.
30. Information overload.
36. Virtual reality.
38. Messaging.
42. Distributed interactive simulation.
43. Generic vs. specialized tools.
44. Real-time conferencing for collaborative analysis.
50. Information push/pull and system drivers.
51. GIS vs. map viewers.
52. COE vs. cost/ flexibility/ evolution.
53. Target decision making performance.

Decision Support Tools: Information needs

1. Operator requirements
2. Prototypes (applications)
3. Operator/scientist interaction
4. Data availability
5. Common look and feel (GUIs)
6. H/W and operating system destination
7. Simulation to provide support for operational decisions
8. Ranking of threats in order of priority
9. Which functions need decision support?
10. Data (information) requirements by user
11. What decisions need to be made
12. What data (information) is needed to make those decisions

13. How (what methodology, mechanisms, statistics) are used to make the decisions
14. Is it better to go at decision support tools rather than decision automated tools?

Decision Support Tools: Creative solutions

1. Enemy deployment/activity recognition patterns available on line
2. Real-time simulation vs. Just-in-time (real time data or just-in-case updates)
3. Multiple simulation scenarios
4. Make inventory of present models and tools

Decision Support Tools: Benefits

1. Faster reaction capability
2. Better use of limited resources
3. Better informed decision process
4. Common response to a given input?
5. Ability to cope with vast amounts of information
6. Reduce stress
7. Better and more timely solutions
8. Support available at all levels
9. Minimize cost of operation
10. Maximize capability

Decision Support Tools: Problems

1. Users stop thinking through the problem, become machine dependent to make decisions
2. Decision makers may not use them
3. Decision makers may use them incorrectly
4. Data may not be available
5. They may not be used if decision makers feel they are slowing the process (hindering) rather than helping
6. Run risk of over automating. People will get lazy and not check up on computer
7. May spend money to develop something that no one will ever use because it is either not needed or not wanted

Decision Support Tools: Gut feeling

1. Decision levels must be researched but we need to ensure the scientists talk with the operators to see what is required, how it should work and what it should look like
2. We will be driven to maximize use of decision support tools due to inevitable downsizing of CF
3. Research required to reduce decision time required to react to ever improved threats
4. Fear of one vendor coming in to wow senior management, and then senior management mandated that tool is now standard to be used

CONCEPT G: SYSTEM ACQUISITION

17. System evolution vs. replacement.
22. Commercial off the shelf.
31. Certification.
32. Requirements capture.
33. Multi-mission support.
34. Acquisition process (departmental commitment).
36. Virtual reality.
42. Distributed interactive simulation.
49. Hardware technologies (mini, rugged, high resolution).

System Acquisition: Information needs

1. What type of system do we want to buy. A single basic hardware configuration for all users or any system that can support a common data format
2. Driving factor is to minimize cost while maximizing capability
3. Need to allow lots of room for system growth so as to avoid or put off obsolescence
4. Portability/flexibility of porting code to new operating system upgrades and hardware upgrades
5. Availability of technical hardware support
6. Availability for replacement components globally
7. Is system an open (flexible) architecture
8. Can system cope with magnitude of problem
9. Can we streamline purchasing process
10. O&M consideration - must consider cradle-to-grave costs

System Acquisition: Creative solutions

1. Technology watch
2. COTS modified to meet Canadian requirements
3. Open system architecture
4. Fix cost of project within reason, but not the design - allow design to migrate with technology
5. Evolutionary development of operational systems
6. Decision to buy at least a limited number of systems made up front (helps in the export potential for the system)

System Acquisition: Benefits

1. Obtain a good knowledge of what systems exist now and may in future - technology watch
2. Will help scientific/engineering staff in new system development
3. Will allow users to obtain fielded systems
4. Life cycle management - plan
5. Standardization
6. Standing offer COTS solutions/cheaper/faster acquisition

System Acquisition: Problems

1. COTS may lead to less reliable systems
2. Evolutionary design of systems may go against standardization
3. This is rather a management problem
4. Lack of mechanism to exploit R&D findings or breakthroughs
5. No R&D - operational system direct pipeline between research establishments, industry and operational community
6. Senior management/TB not willing to accept the increased risk that comes with a streamlined procurement process

System Acquisition: Gut feeling

1. Once acquisition process has been fixed, i.e., Streamlines, little R&D involvement - onus shifts to engineers
2. A critical management problem
3. Initial research might be required to make sure system is suitable/flexible/effective
4. Need to find mechanism to speed up data acquisition
5. One COTS platform/software solution not necessarily the best solution. Enforcing one software solution on CF inhibits further R&D by industry - CF becomes subject to ministerial inquiry for sole sourcing

CONCEPT H: DECISION SUPPORT TOOLS

4. Real-time network architectures.
11. Data transfer speed.
12. Mobile networking.
19. Wireless Comms.
21. Cyberwar information warfare.
24. Information presentation.
27. Common data dictionary.
29. Distributed C2 and processing.
46. Database synchronization.
48. Data compression.
50. Information push/pull and system drivers.
51. GIS vs. map viewers.
54. Data archiving.

Decision Support Tools: Information needs

1. What data do we need to manage
2. Who needs the data
3. How timely must the data be
4. CF data dictionary or multinational data dictionary
5. Don't need a single database between allies but data format must be compatible / essential
6. Data must be available on request
7. Data should be available from multiple sources in case where primary source is unavailable
8. Old data needs to be purged to avoid clutter and to control database size
9. Archival procedures adapted to each operational need
10. Level of interoperability sought versus affordability/maintainability
11. Distributed database technology
12. Data reliability/accessibility requirements

Decision Support Tools: Creative solutions

1. Compatible data models among services/nations
2. Inherent current management information systems/redesign
3. Examine system in use by large commercial firms like federal express
4. De-centralize databases to reduce risk and provide redundancy in times of conflict

Decision Support Tools: Benefits

1. Consistency among systems
2. Better information flow to commanders
3. Product availability for users
4. Corporate knowledge base

Decision Support Tools: Problems

1. Dependent on architecture
2. Industry resolves problem first/better (been working issue for years - SyBase/Oracle) for stock exchanges, banks, etc.
3. Can not ensure data integrity with resulting R&D product
4. CF does not agree on data requirements/architecture
5. It would take too much effort to agree on an overall common joint data management/distribution procedure
6. Dependency on 'national doctrine'
7. Too slow to respond to user's change request
8. Data access/Control

Decision Support Tools: Gut feeling

1. Very important R&D supports data requirements capture and help out finding solutions to management of data and distribution
2. Need for common data structures to ease/simplify development
3. If you can't get the data to the user, the rest of the R&D is wasted. Pick a data structure and transmission standard first
4. Very important because more and more data will be available (information watershed)

CONCEPT I: ARCHITECTURES

7. Scaleable systems.
9. Load management.
11. Data transfer speed.
12. Mobile networking.
13. Low/ medium/ high intensity conflict support.
16. Component commonality (OEM).
17. System evolution vs. replacement.
18. Peacekeeping support.
19. Wireless Comms.
20. Platform independence (common interfaces).
26. Interoperability with external systems.

28. Graceful degradation.
29. Distributed C2 and processing.
33. Multi-mission support.
36. Virtual reality.
50. Information push/pull and system drivers.
51. GIS vs. map viewers.
54. Data archiving.

Architectures: Information needs

1. Commonality with the US NATO systems
2. Need to know capability in private sector
3. Decision on type of system development
4. Client requirement capture
5. What are advantages/disadvantages of various system architectures
6. What architecture does GCCS allow
7. What is processing power required
8. How flexible can we be
9. Architecture must be robust
10. Need to have scaleable architecture to allow for deployable systems, vehicular systems and portable systems
11. Architecture must allow for expansion to accommodate new requirements
12. Standards
13. Real time requirements
14. TBMCs/COE vs. API Definitions

Architectures: Creative solutions

1. Architectures standard interfaces
2. Interoperability interface data base and requirements system (US - SOI)
3. GCCS/TBMCs
4. Plug and play systems
5. Use parallel processing with multiple PCs
6. Use of COTS methodology to capture military 'business' processes in order to design better systems

Architectures: Benefits

1. Minimize learning curve for officers on posting move
2. Inter-operation of system between services and between allies
3. Client-server architecture
4. Distributed databases
5. Distributed processing/ parallel processing

6. Lower cradle-to-grave costs
7. Access to a potentially world-wide network of information
8. Hardware can be replaced without replacing/modifying software
9. Simpler supply/O&M costs

Architectures: Problems

1. If we choose a specific architecture it will become obsolete and will limit future growth
2. By selecting an existing architecture we must accept its limitations
3. 'Tied to US Architectures anyway'
4. Will change their mind!! Leave us in the cold
5. TBMCs and GCCS are not compatible (Cobra vs. DCE) -- if we go to one, the US will go to the other (Murphy's Law)
6. Common hardware does not mean common software, i.e., Source country may not provide the latest or best software

Architectures: Gut feeling

1. Architecture will fall out of system design, not really an R&D area on its own
2. Can either go with a common architecture or a common data structure. Each has its own advantages
3. Determine most efficient designs
4. R&D has a major role to play in architecture design to ensure user's requirements are captured and validated in the most illustrative way through prototyping which could be too costly to industry to pursue

PRIORITIZATION

VOTING SUMMARY

	P1	P2	P3	P4
A. Data acquisition/ fusion	1	5	1	8
B. Standards	8	3	7	1
C. Security/ protection	7	8	2	9
D. Man-machine interface	3	6	4	4
E. Support	5	9	6	7
F. Decision Support	2	4	3	3
G. System acquisition	9	7	9	2
H. Data distribution	4	1	8	5
I. Architecture	6	2	5	6

AVERAGE RANK

	Average Rank
A. Data acquisition/ fusion	3.8
B. Standards	4.8
C. Security/ protection	6.5
D. Man-machine interface	4.3
E. Support	6.8
F. Decision Support	3.0
G. System acquisition	6.8
H. Data distribution	4.5
I. Architecture	4.8

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A workshop on Command and Control (C2) sponsored by the Chief Research and Development (CRAD) was held in Ottawa on 7-9 May 1996. This forum brought together CRAD scientists and Canadian Forces (CF) officers to provide input on strategic planning for Command and Control Research and Development (C2 R&D). Specifically, the group was tasked to address the "what" and the "how" of C2 R&D. This report documents the results of structured brainstorming exercises on the requirements and opportunities (the "what") for C2 R&D in the near to mid-term. A companion paper documents the structures and processes (the "how") recommended to implement productive C2 R&D.

Distinct themes emerged from the syndicate exercise identifying areas for further R&D. Decision support systems and planning tools must be developed to exploit information made available through C2 Information Systems (C2IS). Methods and procedures must be developed to monitor the performance of C2IS. Research is required in determining effective processes for large project C2IS life cycle management from user requirements capture to end user support. Strategies for information management including must be developed and built into system architectures. Standards need to be developed for information presentation. Effective programs must be established for initial and operational training. Finally, doctrine must be examined in light of how C2IS technology could assist the CF in achieving its missions. Although present research programs address many of these areas, CRAD does not have the resources to mount major research programs in each of these fields. There was a sense that realignment of research efforts based on a multi-disciplinary team approach may yield better results. Ideas generated and developed by the syndicates are provided in the Annexes.

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